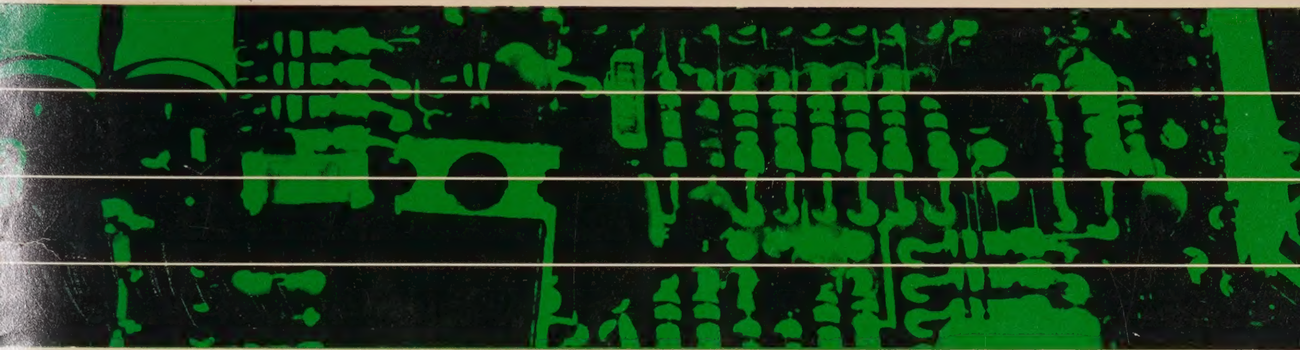

# MICROELECTRONICS
# Background Papers for the Task Force to the Government of Ontario

October 1981

MINISTRY OF INDUSTRY AND TOURISM

BACKGROUND PAPERS

FOR THE GOVERNMENT OF ONTARIO

MICROELECTRONICS TASK FORCE

OCTOBER 1981

## MESSAGE FROM THE MINISTER

The revolution in microelectronics is having a profound affect on our industry and society. In the past few years, the application of semiconductor technology has begun to transform a wide range of manufacturing processes and has changed many of the traditional ways firms and individuals conduct business. The rapid diffusion of microelectronic technology will continue, and at an increasing pace.

In this rapidly changing environment, microelectronic breakthroughs bring with them not only the promise of a more efficient and productive economy, but also the inherent difficulties of adjustment for industry. Smaller firms, which must adapt quickly if they are to remain competitive, will find the transition to this new technology especially difficult, but essential.

In order to address some of the broader industrial, labour and social implications of microelectronic technology, the Ontario Government established a Task Force composed of leaders drawn from industry, labour and government.

To facilitate the deliberations of the Task Force, background papers were prepared by my Ministry staff. Because these papers provide information on a wide range of topics concerning the industrial impacts of microelectronic technology for both Ontario and Canada, we have decided to make them public.

I would hope their publication will prove useful both to the general reader and to the specialist who may require a more detailed review of the topics discussed.

Larry Grossman
Minister of Industry and Tourism

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## INTRODUCTION

Since the beginning of time there have been inventions and discoveries whose eventual proportions have been so immense that they have virtually changed the course of mankind. The discovery of both fire and the wheel were more by accident than by research yet without them James Watt would not have invented the steam engine and the Industrial Revolution might yet have not occurred.

Technology has grown so rapidly in the last few decades of this century that it is difficult to assess the relative importance of each new development. History will be the final judge but there can be little doubt that the transistor - which led to the microprocessor - will rank as a major discovery. It is also probable that the period in which we live today will be hailed as the start of the microelectronic revolution. Some already rank it as equal in importance to the Industrial Revolution itself.

What are 'microelectronics', why and how will they affect our industries? This is what these background papers examine.

In March 1980, the Speech from the Throne to the Ontario Legislature announced the following intention:

> "In a new initiative, Ontario will establish a working group of private and public sector experts dealing with computer chip and microelectronic technology, to ensure optimal benefit for the industries and people of Ontario from technological developments in this increasingly important area."

The Speech from the Throne indicated the government's recognition that there was a necessity for the development of suitable policies to capitalize on the industrial benefits which could accrue from this new technology. At the same time, the Speech from the Throne acknowledged that the introduction of any such major technological change could bring with it a major impact on the basic structure of society. A Task Force on Microelectronics was subsequently established with representation from industry, labour and government.

There is a considerable wealth of data published about the field of microelectronics. Inevitably, much of this material is repetitive since it has been produced by independent and non-coordinated research. Much of it may deal with specific facets of the technology's implication reflecting either the perception of the authors or the instructions of those requesting the study.

Since the material has been prepared in a number of countries, it can exhibit local conditions or concern. Some of these concerns are coincident with those applicable to the Canadian scene; others could have little relevance.

Although many aspects of the future impact of microelectronics technology were advanced in the literature, there were key elements which clearly indicated areas of prime concern. These were:

- The industrial opportunities implicit for Ontario in the use of microelectronics technology by companies inside and outside the electronics industry.
- The impact on labour in terms of new jobs to be created and the skills required for these jobs.
- The need for retraining of the existing work force and the necessity to change the number and types of graduates of the educational system.
- The possible impact on the general lifestyle of the populace.

To assist the Task Force in its deliberations these areas were examined by ministries within the Ontario Government whose day-to-day activities included such responsibilities. It was recognized from the outset that there could be no sharp lines of demarcation of authority and responsibility due to the inherent interrelationship of these concerns. However, by acting as a coordinated secretariat the inputs from all ministries could be combined at the Task Force level. Accordingly, the following responsibilities were assigned:

| Subject | Ministry |
|---|---|
| ° Industrial development and diffusion of technology | Industry and Tourism |
| ° Labour implications | Labour and the Ontario Manpower Commission |
| ° Retraining and education | Education and Colleges and Universities |
| ° Lifestyle implications | Transportation and Communications |

Although the actual methodology varied between ministries, the basic method employed a number of interviews with Canadian and U.S. industries both directly and indirectly associated with microelectronics manufacture and use. Government agencies, research institutes and informed observers were also interviewed.

A distillation of some of these inputs has been used to prepare various background papers on topics of possible general interest. The enclosed papers touch on microelectronics technology, the Ontario/Canadian electronics industry and selected areas of industrial and business development opportunities. The references listed at the end of each paper and the Selected Further Readings on page 121 might prove useful to readers who are interested in pursuing some of these subjects in greater depth.

Other ministries will also publish background papers covering the results of their investigations.

The final report prepared by the Task Force on Microelectronics made use of the findings reflected in these background papers. The Task Force Report makes specific recommendations for appropriate policies and programs to be implemented by government, industry, educational institutions and labour.

## EXECUTIVE SUMMARY

### Synopsis

For Canada, the adoption and diffusion of microelectronic technology is both a necessity and an opportunity. The necessity arises in relation to the current performance of Canadian industry in the world environment and the intensified competition which our industry will face as we move through the 1980s.

Canada currently runs a substantial deficit in trade in manufactured goods. In the decade ahead the reduction in trade barriers, continued efforts to offset deficits on the energy account around the world, and the emergence of the newly industrializing countries will see increased competition for our industry in both domestic and international markets. Technological performance will be a key determinant in upgrading our manufacturing capability to meet these challenges. In particular, the adoption and diffusion of microelectronic technology can allow:

- the development of specialized products, services and systems at the front end of the product life cycle where opportunities for establishing a competitive edge are greatest;

- substantial improvements in productivity and cost competitiveness through the adoption of advanced process technology.

The opportunities inherent in the adoption and diffusion of microelectronic technology lie in the strengths which Canadian industry has already developed in specialized areas of electronic products and systems. As the telecommunications and information processing technologies merge over the next few decades, and the "Information Society" evolves, the potential for further development of this base is enormous.

### THE CANADIAN ELECTRONIC INDUSTRY

The electronic industry can be broken down into three interrelated product groupings: components, hardware and software. The hardware sector can be further broken down to include electronic products such as radio, television, calculators and watches, computers, telephone and communications equipment, word processors, and other office machinery and a range of instrumentation equipment and controls. Software is the detailed and complex instructions by which the hardware is programmed to execute its functions.

Using the Statistics Canada Standard Industrial Classification, the electronics industry is made up of four segments:

- 318 - Office Machines
- 334 - Household Radio and Television
- 335 - Communications Equipment and Electronic Components
- 3911 - Instruments and Related Products.

The apparent domestic market (shipments plus imports minus exports) for electronic products in 1980 exceeded $6.8 billion. Shipments of domestic manufacturers were $4.3 billion. Net imports were just over $4.5 billion and exports not quite $2 billion, leaving a trade deficit of more than $2.5 billion.

Industry employment reached a peak of 75,457 in 1974. In 1980, total employment was 65,323, with about two-thirds of the jobs located in Ontario. In recent years there has been a loss of low-skilled jobs to low-wage countries, but the industry has remained a key employer of highly skilled manpower.

There are few market or other restrictions on the location of the industry. Government incentives have come to play a major role in the industry's development. Incentives offered by governments include: direct procurement, research and development assistance, protectionist measures and direct financial support.

The United States is Canada's largest trading partner in electronic products. In 1980, 78 per cent of imports were from the United States and 64 per cent of exports were shipped to the United States.

The annual average growth rate of shipments over the last seven years has been 6.3 per cent in real terms. The apparent domestic market and imports have grown at average annual rates of 8.1 per cent and 13.5 per cent, repectively. The gap between the growth rates of shipments and the domestic market is narrowing, but the trade deficit is increasing in absolute terms.

Over 67 per cent of the industry is foreign-controlled. Seventy-two of the 100 largest firms are foreign-controlled. With the foreign-controlled group, 20 per cent account for 55 per cent of industry sales.

In 1980, the electrical and electronic products industry spent $168 million on R & D, or about 3.6 per cent of gross sales. The comparable figure for all manufacturing industries is 0.8 per cent.

## Microelectronics - The Core Technology

The genesis of the electronic industry can be traced to the development of the vacuum tube. The impact of that tube can be easily grasped by imagining a world without radio or television. It introduced the opportunity to use electricity not just for energy-related uses such as lighting, heating and propulsion, but for the more sophisticated tasks of communication, control, calculation and sensing. It is this capability--this "intelligence" function--which distinguishes electronics from the electrical industry.

A major breakthrough in electronic technology--and the birth of microelectronics--came with the development of the transistor in the Bell

Laboratories in 1948. This began the process of miniaturization and integration which has brought us to the complex integrated micro-circuits* of today. Microelectronics is a term coined to describe these new components, their manufacture, application and utilization. The reduction in component size made possible by developments in the technology, together with increased component capability and decreasing cost, have opened up dramatic new opportunities for product and process innovation across a broad range of industries and applications.

The semiconductor component sector is a key element of the electronic industry. Integrated circuits have the largest and fastest growing share of this group. Production is dominated by the U.S. which accounts for about 71 per cent of world production of integrated circuits while Japan accounts for approximately 16 per cent and Western Europe, 6 per cent.

There has been an increasing trend toward vertical integration in the electronic industry as semiconductor manufacturers expand into the production of end-products. Conversely, equipment manufacturers are establishing and expanding in-house design and production capability for integrated circuits.

There are many reasons for establishing captive semiconductor capabilities. The resulting close coupling between component and product technologies, security of supply and protection of proprietary know-how, are major factors.

The cost of establishing a new integrated circuit design and manufacturing facility has been increasing rapidly and is dependent on the sophistication and production volume of the devices to be made. An investment in the order of $50 million (U.S.), or more, is required today to establish a large scale facility.

Canadian presence in the production of electronics components in general, and semiconductor devices in particular, is limited. Nevertheless, while most semiconductor devices used in Canada today are imported from the U.S., some Canadian capability is being developed. The major thrust is related to custom designed circuits for communications application. The development of this capability is illustrative of the synergy between systems know-how and semiconductor technology.

Overall, it appears that the opportunities for production of general purpose integrated circuits in Canada is limited for the immediate future. However, special purpose chip capability will be essential to the establishment of a competitive edge in hardware and systems development and the creation of the synergy so important to further advances.

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* Also referred to as 'chips' or 'silicon chips'. This is discussed more fully on pages 23 and 24.

## Software

The term software has traditionally been associated with the computer industry. In general, software is the means used to communicate with hardware and by which we provide the intelligence that determines and controls what the equipment does. More specifically, software includes computer programs, programming languages, routines and procedures to be followed, program listings and documentation.

Software is an increasingly important element in the design and application of microelectronic circuits, and in electronic equipment and systems. Software is, in fact, emerging as an industry in its own right with hardware as the means of production and intellectual content as the product.

Many in the industry feel that the capability of producing software and the cost of software may constrain the growth of the electronic industry and inhibit the application and utilization of electronics in other industries. The projected demand for software people exceeds the anticipated supply.

The major producers of software have historically been the computer manufacturing firms. The U.S. dominates the market and will continue to do so for the foreseeable future. However, Japan is moving to accelerate software development. In Europe, the United Kingdom has a reputation for excellence. France and West Germany are also well represented.

Several reports have suggested that Canada excels in certain areas of software and that we have an opportunity to capitalize on our expertise in the international marketplace. Canadian companies are, for example, selling their software and software services in the international marketplace. It is, however, generally agreed that there is substantial room for improvement, both to facilitate further development of Canadian capability in the electronic industry overall and to capitalize on the potential opportunities in this fast-growing sub-sector of the industry.

Key issues determining the future rate of development are simplification and standardization of computer languages; improvements in and the availability of software development tools; provision of adequate legal protection through copyright; and availability of manpower.

With specific reference to Canada and the role of government, two further issues are important:

- the level of support vis-à-vis other jurisdictions;
- the tax and tariff treatment of computer hardware and software.

## Diffusion of Technology

The adoption and diffusion of microelectronic technology is crucial for the maintenance and development of Canada's competitive performance. With a growing body of literature on the diffusion of technology in Canada, a clear picture is emerging which leads to the conclusion

that Canada is failing in its rate of technological progress and lags in the application of knowledge and information.

This slow rate of diffusion is evidenced in microelectronics technology. For example, in the tool and die industry, which has the potential for extensive use of numerically controlled (NC) equipment, it has been found that the percentage of U.S. firms using this technology was consistently higher than in similar Canadian firms throughout the 1960s and early 1970s. The result of a 1981 survey conducted by the Government of Ontario's Ministry of Industry and Tourism and the Ontario Research Foundation, found that about 2 per cent of all machinery in Canada was numerically controlled. In comparison, the rate of application of NC machine tools in the U.S. was estimated at 9 per cent of all metal-cutting machine tools in the machinery industries in 1976.

In the important field of computer assisted design and manufacturing, there is a growing feeling that Canada lags substantially in the application of this technology. In the installation of robots, Canada trails all major industrialized nations. According to estimates by the Department of Industry, Trade and Commerce, there are over 200 industrial robots throughout the country compared to over 4,000 in the U.S. and an estimated 10,000 in Japan.

Similarly, Canada also lags in the utilization of office automation and of computer technology in selected service sectors such as hospital administration and retail and wholesale outlets.

The potential for increasing the pace of diffusion--in industry, in the office, in institutions and in the home--will depend on a variety of factors, including:

- the role and level of government support;
- the adequacy of the technological infrastructure;
- a recognition of the interdependence of the sub-sectors within the industry, i.e., components, hardware, software;
- the availability of an appropriately trained labour force;
- improved labour-management relations;
- acceptance by society.

## Office Automation

Advances in microelectronics technology have led to announcements of a revolution in the office. The major benefits of office automation are the timely dissemination of information, in a form that is useful to decision-makers, as well as the increased efficiency of the office environment.

Although the chief constraints to introduction will likely be socio-economic, advances in hardware and software technology will also play a major role.

The concept of the automated office involves unifying the functions of telecommunications, word processing, data processing and image processing. The key to its long-term success will be equipment compatibility and the ability to communicate with other office systems.

The future for companies supplying goods and services to this market is bright. Areas of current research activity include voice recognition, graphic displays, telephone technology leading to simple management of digital data, new imaging devices, "smart" copiers, and distributed systems based on minicomputers. Many of the products will also find their way to the educational and home markets.

The number of computers is expected to undergo rapid growth with most of the growth accounted for by small computer systems. The colour graphics market will experience particularly fast growth. The market for word processors is also expected to grow rapidly. There will be a shift away from stand-alone to multi-terminal systems.

Within the office automation industry, word processing equipment manufacturers have been Canada's success story. Canadian industry has also had some success in small computers and peripherals. However, in order to secure future success, it will be necessary for domestic producers to:

° secure supplies of custom, special-purpose, integrated circuits, and

° develop an ability to attract sufficient financing for growth purposes.

Both of these conditions are especially important for small firms.

## Communications Equipment

Communications and components comprise approximately 46 per cent of Canadian electronic industry production. Within this group, communications equipment represents our major strength. The potential for growth is tremendous. The past ten years has witnessed a universal demand for more and better communications equipment and the information it can provide.

This trend can be expected to continue over the next five to ten years. The total world market for telecommunications equipment is estimated at $40 billion (U.S.) for 1980. By 1990, it could reach $87 billion (U.S.). Despite the diversity in products, company sizes and markets within the Canadian industry, two factors clearly emerge. First, the successful companies in each group are those who have selected a specific product and market niche and developed their basic corporate strategy around them. Second, part of this corporate strategy involves substantial R & D funding.

Product innovation will be a key to continuing success in the industry. In addition, market access, both within Canada and internationally, will also play a major role in the success of these communications firms. Foreign markets are currently characterized by non-tariff barriers to trade.

## Instruments and Controls

This sector includes a range of specialized equipment of a generally sophisticated nature. In addition to industrial process control, instrumentation and automation equipment and systems, it includes:

- building instrumentation and automation equipment and systems;
- biomedical and health care instrumentation;
- electrical, electronic data and logic test and measurement instruments and systems;
- scientific, analytical and laboratory instrumentation;
- remote sensing and environmental instrumentation; and
- geological, geophysical and geotechnical apparatus.

The sector exhibits the pattern typical of the electronic industry in Canada--a small number of large subsidiaries of foreign multinational companies and a large number of small Canadian-owned companies. The former produce product lines typical of their parent facility. The latter produce highly specialized products for custom applications.

World markets for instrumentation and control equipment and systems reached an estimated $20 billion (U.S.) in 1980. Electro-optical equipment used in industry, resource and energy exploration, showed the fastest growth over the period 1976-1980.

The United States represents Canada's major export customer and supplier of instrumentation and control equipment. However, industrialized markets outside North America also show a degree of acceptance of Canadian products. Major Canadian companies are capable of taking instrumentation and control systems from concept through design and installation on a turn-key basis. This can include software development, hardware production or procurement, operational training of customer personnel, and installation, service and maintenance.

In order to succeed in these new markets, a number of conditions have to be met. These are:

- continued product innovation and an associated high level of R & D expenditures;

- an ability and willingness to serve international markets. Availability of finance for exports is an important issue, particularly for smaller firms.

- availability of skilled personnel. Systems designers, software engineers and technicians are in increasingly short supply. Again, this issue is particularly important for the small company.

## Automated Manufacturing

With developments in microelectronics, there remain few technological barriers to the advent of the automatic factory. Socio-economic factors, rather than technological limitations, are behind its slow emergence. Cost-effectiveness, availability of capital, and labour force impacts are key factors in determining the rate of introduction.

The imperative for Canadian industry to remain competitive with leading industrial nations, however, dictates the need for increasing automation. It is now generally accepted that a key reason for the lag in productivity growth of North American industry is due to low levels of long-term investment in technology and modern plant facilities.

Until the advent of cheap, reliable, programmable electronics, automation was only feasible in mass production environments. Because automated systems based upon intelligent electronics can be reprogrammed to produce a variety of generic products, they have come to be known as 'flexible automation'. Flexible automation makes feasible the automation of batch production whose volume would otherwise only justify manual facilities.

This is especially important when viewed in the context of the generally small scale, fragmented production structure which characterizes much of Canadian manufacturing.

The world market for machinery and equipment is, today, very competitive. Virtually all automated manufacturing equipment consumed in Canada is currently imported. This points to substantial import replacement opportunities. Given the small scale of the Canadian market for specific equipment needs, however, future suppliers would need to look at a broader market base as well, e.g., the U.S.

The largest single market for CAD/CAM (computer aided design/computer aided manufacture) equipment is the United States. It is the world's largest producer, consumer and importer of machine tools. The automotive industry is a particularly important market. Others include the aerospace industry, other durable goods industries, and manufacturers of electrical/ electronics products, machinery and metal parts.

For a Canadian manufacturer to supply equipment markets--particularly for CAD systems and robots--the following are essential:

- an ability and willingness to compete in U.S. and world markets;
- provision of adequate support services such as design and applications engineering, and training;
- a strong presence, through industrial cooperation, in served markets;
- a strong R & D capability;
- a strong software capability.

## Automotive Electronics

Electronic components are playing an increasingly important role in automotive production. By 1985, the U.S. market for such components is expected to exceed $1 billion. If entire automotive electronic sub-systems are considered, the market is estimated at $4 to 5 billion.

Major opportunities relate to:

- ignition systems
- engine and transmission controls
- fuel systems
- safety systems
- instruments, comfort and convenience features, including dashboard displays
- entertainment products.

The vehicle manufacturers will play a major role in the development and production of electronic components and sub-systems. However, there will also be a role for independent suppliers.

The Ontario automotive electronics industry is comprised, generally, of three companies, all of which are subsidiaries of United States multinational corporations. Efforts are currently underway on the part of vehicle manufacturers to develop further sources of supply. The success of Canadian firms will depend, to a large extent, on their ability to support substantial R & D, produce to large-scale requirements, and ensure quality control.

## Electronic Consumer Products

Perhaps in no other field has the application of integrated circuits been more obvious and pervasive than in consumer goods. About 29 per cent of all chips produced in 1980 were utilized in such products. The application of microprocessors has not only transformed the nature of traditional products such as watches, but has also led to the creation of entirely new products such as hand-held calculators.

It is estimated that the rate of change in consumer electronics will be such that, as we move through the 1980s, the sale of new chip-based products in the U.S. will surpass that of traditional products such at TVs, radios and hi-fis. These new products will not necessarily replace existing consumer goods, but will create new primary demand, thereby competing for consumer disposable income with other household products and services.

By 1990, the average household will have over 1 million bits of memory and logic compared to 1000 bits in 1980.

The U.S. is the largest producer and consumer of chip-based consumer products. It continues to dominate the market for toys and games. However, the Japanese have also established a major role in selected product areas, e.g., calculators, and watches. In terms of future market development, the greatest potential is perhaps in home computers. The current leaders are Apple, Radio Shack and Commodore. Microprocessors are also making extensive inroads in the domestic appliance markets. The most extreme case is in the U.S. microwave oven market, where chip-based products account for 60 per cent of sales. In the overall U.S. electric range market, penetration of microelectronics represented only 1 per cent of sales in 1978, but this is expected to grow to 15 per cent in 1980 and 30 per cent by 1985. Similar penetration can be expected in other appliances.

Canadian consumption of consumer electronic products is satisfied primarily from imports. The relative decline in our own manufacturing capability can be traced to small market size, the inability to produce to scale, and the difficulty in supporting an intensive R & D and design capability.

The future of the Canadian electronic consumer products industry will not generally lie in traditional or new product areas where economies of scale play a major role, but rather in the pursuit of specific market niches based on Canadian-developed technology and in softer areas of consumer information services. In this respect, Telidon may provide a major opportunity. While demand for this service will come initially from business, industry and institutions, reduction in the price of terminals could dramatically increase the potential for home market terminals.

## THE CANADIAN ELECTRONIC INDUSTRY - OVERVIEW

### Definition

Any analysis of the Canadian electronics industry should be prefixed by the caveat that it would be difficult to describe or find a typical company in the industry. Company size, location, products, markets, technology, manufacturing methods, ownership, years in business, vary across a wide spectrum.

Such variation is, of course, not by chance. The reasons lie at the heart of the industry itself.

The term 'electronic industry' would suggest a homogeneity which simply does not exist. The only common denominator is that each company in the industry may be said to use electricity for 'intelligence' as opposed to the electrical industry which uses it for energy.

Within the context of this report the term microelectronics is used to describe, or modify, all semiconductor devices--whether of a discrete or integrated circuit-type, products and systems using these devices, and the companies producing either such components or equipment.

The equipment manufacturers who use microelectronics are not readily identifiable and could only be distinguished by a detailed examination of the product itself. However, since it is the latest technology in electronics, it is reasonable to assume that virtually every electronics manufacturer for whom product cost, reliability and size are important factors will choose, or be forced by competitive pressures to adopt, microelectronic technology. Therefore, microelectronic manufacturers will soon be synonymous with electronic manufacturers. The industry makes three basic products

- Components
- Hardware
- Software

and by combining these products makes 'electronic systems' of almost limitless diversity.

### Components

The manufacture of electronic equipment is, generally, an assembly operation of a number of individual parts or components. Some of these individual components can be of a highly specialized nature, specifically designed for a particular product and produced in limited quantity and at high cost. However, most components have, until recently, been of a standardized type produced in large volumes and sold at relatively low prices. The complexity of the assembled product has, therefore, been due less to the types of

components used than to the manner and circuitry in which they were employed. Resistors, condensers, vacuum tubes, and individual semi-conductor products--transistors--were typical of such high-volume, low-cost components used as discrete circuit elements.

One of the prerequisites of such high-volume component manufacture is a high-volume market by which they are consumed. The household radio and television receiver provides such a market. Not only does radio and TV provide a steady demand for the 'bread-and-butter' components, their strong support of the component manufacturers permit these suppliers to make specialized components of the same type. The virtual demise of domestic Canadian radio and television manufacturers, which will be discussed later, was, therefore, a serious blow to the component industry that had relied so heavily on it.

This in turn reduced the Canadian supply of the specialized components used by manufacturers of other lower-volume electronic equipment. Even if the decline in radio and TV manufacture had not been the cause of a corresponding decline in component manufacture, the industry would have still been subject to massive changes for technological reasons, specifically microelectronics integrated circuits combining thousands of circuit functions on a silicon chip the size of a fingernail.

The Canadian component manufacturers who continue to supply the needs of the domestic manufacturers, and a growing export market, concentrate their production on specialized items. These include the following:

| | |
|---|---|
| Antennas | Loud speakers |
| Printed Circuit boards | Relays |
| Coils | Resistors |
| Connectors | Semiconductors |
| Crystals | Switches |
| Filters | Transformers |
| Iron cores | Tubes - including cathode ray |

Components such as batteries, motors, and cast, stamped and other machined metal parts, are also available but are covered under other industry designations than 'electronic'.

Hardware

This covers a diverse range of electronic equipment from television to telecommunications, calculators to computers, radio to radar, typewriters to telephones and an infinite range of instruments and related products.

The overall markets and shipments for these products are provided in this section and the products themselves discussed in detail in subsequent chapters.

## Software

Although a computer is capable of performing a myriad of tasks at speeds approaching the speed of light, it does not and cannot do so without detailed and complex instructions. These instructions are called 'software.' Specific programs are developed to produce a desired end result whether it be a company payroll, accounts receivable and payable records, vehicle or equipment maintenance schedules or calculating the complex path of a satellite through space.

Although the need for software was originally confined to data processing equipment it has become far more pervasive. Microelectronic components and the circuits in which they are employed have reached such complexity that their design also necessitates the use of the logic associated with instructions to EDP equipment.

It is quite certain, that the use of and demand for software and personnel competent to develop it, will grow directly with the ever-increasing use of microelectronics.

## Basis of Competition

Many industries have major practical restrictions on their location. The needs for access to raw material supplies, abundant, cheap and dependable energy, major transportation systems or large labour pools, may seriously limit their choice of acceptable plant sites within a country and indeed within the world. If their finished product is heavy or bulky world freight costs may dictate proximity to their major customers. Other manufacturing processes may need water for coolants, or generate noxious fumes or effluents as a by-product and may further narrow the choice acceptable both to the manufacturer and to his neighbour.

The electronic industry exhibits virtually none of these characteristics. Its manufacturing processes are generally clean and consume little energy or raw materials. The products are light on a weight/value ratio and can be shipped economically worldwide.

Depending on the product, assembly skills can range from unskilled to skilled but typically the work force is predominantly female and readily available at the skill levels required. Technical staff is more difficult to obtain and retain.

A 1978 Federal Government study on electronics used the word 'footloose' to describe the industry. This designation was not intended to be critical of its stability but rather to describe its high degree of freedom in its

choice of location. This siting freedom has resulted in a very large electronic industry emerging in Japan, Korea, Taiwan, Hong Kong and Malaysia. Under strongly nationalistic support, Mexico and Brazil are also emerging as major electronic locations.

Because the industry is fully international its products do not usually have pronounced national characteristics. Some products such as television receivers and broadcasting equipment may have to be produced to satisfy national broadcasting systems standards, e.g., the French SECAM, the British PAL or the U.S. NTSC, but these are exceptions to the rule.

This provides both opportunities and problems for the Canadian manufacturer. He can design products and build facilities aimed at world markets which in total are 25-30 times the Canadian domestic market. But because this domestic market is equally accessible to foreign manufacturers, he is not assured of any protection for sales in Canada.

This means that competition is based mainly on price and features. Quality, reliability, delivery and other such considerations are of major importance in the initial evaluation but can, after all, really only be established after the order.

In this environment the Canadian high technology companies have faired well. A typical shipment pattern is for 75 per cent to go to export markets and 25 per cent to domestic customers. Even a company with as large a domestic market as Northern Telecom has announced an objective of a 50/50 split between export and domestic sales.

Another factor that does influence effective competition is government policy. North America is unique in the fact that most of its telecommunications systems are privately owned. In virtually every other country such systems are under the control of the local federal government. Not only is the matter of telecommunication itself deemed to be of strategic importance, so also is the encouragement and sponsorship of a domestic industry that can serve its needs.

This policy, adopted by the major industrialized nations, limits or precludes Canadian participation in meeting those nations' telecommunications equipment requirements. At the same time local manufacturers operating from a secure and protected domestic base, can mount an all-out assault on the Canadian market, which exhibits few such protectionist policies.

Some Canadian manufacturers have partially circumvented these conditions by establishing branch plants in foreign markets by licensing, or by joint ventures.

This has led to the emergence of a highly successful category of business enterprise - the Canadian multinational. Their performance under conditions biased in favour of foreign suppliers is a testimony to excellence of product and entrepreneurial drive.

## Major Industry Sectors

As microelectronic technology has developed, it has been characterized by spectacular improvements in performance and a rapid decline in price for components. These developments have been accompanied by the acceptance of microelectronic components in a wide variety of consumer and industrial products. Microelectronics are not only replacing electronic, mechanical and hydraulic systems in existing products, but also have made many new products feasible. This has led to an industry that is difficult to define using conventional descriptions such as type of product manufactured. Perhaps the most readily identifiable common characteristic of the industry is that microelectronics are used to provide artificial intelligence for measuring, calculating, controlling and other functions.

The pace of change in the industry has, to some extent, outstripped our ability to describe and analyse trends over the years, but the Statistics Canada data presented here provide a reasonably good overview of the "microelectronic industry." Four Standard Industrial Classification (SIC) codes are used throughout to divide the industry into segments. The SIC codes and the main products covered by each are as follows:

- 318 - Office Machines; includes calculators, computers, cash registers, duplicators, word processors, dictating equipment and associated parts.
- 334 - Household Radio and Television; includes phonographs, tape players, television, and radio receivers and antennae. This does not include parts.
- 335 - Communications Equipment and Electronic Components; includes telephone, telegraph, sonar, radar, radio transmitting and receiving, commercial communciations, navigation, railroad signal, alarm and signal equipment. Also included are parts for the foregoing and electronic components.
- 3911 - Instruments and Related Products; includes scientific and test equipment, building environment controls, laboratory equipment, industrial controls, geophysical equipment, photocopiers, microfilm equipment, and associated parts.

It should be noted that, especially in the case of SICs 318 and 3911, some products that do not use microelectronics are included in the above classifications. On the other hand, some newer applications of microelectronics, such as games and automotive electronics, are not included in these classifications.

Domestic Market and Foreign Trade

Domestic market and foreign trade statistics are summarized in Table 1. The apparent domestic market during 1980 for electronics exceeded $6.8 billion and the trade deficit stood at more than $2.5 billion. Imports of office equipment (mainly computers and peripherals) are the largest factor, accounting for $0.97 billion of the deficit. All but 3 per cent of the Canadian market for office machines is supplied by imports while domestic manufacturers export 93 per cent of production. These figures reflect an industry that is highly rationalized on a company basis. Since the domestic market is small in world terms, most of the production must be exported. The high degree of rationalization has made the industry more efficient, but has not led to balanced trade.

The radio and television industry reached a peak in 1973 and then entered a period of severe decline until 1978. In 1973, imports accounted for 45 per cent of the domestic market. By 1978, the figure had risen to 87 per cent. In recent years the industry has recovered somewhat. In 1980, imports had dropped to 74 per cent, but the value of domestic production was only 35 per cent of the domestic market.

Of the four industry segments, Communications and Components is, by far, the largest with shipments of $2.32 billion. More than $1 billion of the shipments were for export, but this level was not enough to offset imports of $1.6 billion, leaving a trade deficit of over half a billion dollars. Despite the large deficit, the Communications and Components industry comes closest to balancing its trade with value of shipments equal to about 81 per cent of the domestic market.

Canada has only one world-scale electronics company, Northern Telecom Ltd. Its sales for the year ended December 31, 1980 were $2.05 billion. At the end of 1980 Northern Telecom operated 30 plants in Canada, twenty in the United States and five in other countries. Though large by Canadian standards, Northern Telecom is only medium-sized by international standards. Worldwide, there are more than 30 electronics companies, of which twelve are communications equipment manufacturers, that are larger than Northern Telecom.

Other Canadian-owned electronics companies are small by comparison to Northern Telecom. The combined sales of all of them amount to less than one-half of Northern Telecom's.

Within the group of Canadian-owned companies, there are several that are growing very rapidly. Mitel Corporation's sales have at least doubled every year for the last several years. Mitel revenues in 1979 were $21.6 million; in 1980, $43.4 million and, in fiscal 1981, $111.2 million. The company is projecting sales of $1 billion by fiscal 1986. Gandalf sales in fiscal 1980 were $26 million and are estimated to be $40 million in fiscal 1981. There are several smaller Canadian-owned companies with similar growth rates. This group of companies is growing much faster than the industry as a whole

and, by the latter part of the current decade, they should be a significant factor in reducing the trade deficit for electronic products.

## Employment

Employment trends over the last decade for Canada and Ontario, respectively, are shown in Table 2 and plotted in Figure 1.

From a peak of 75,457 in 1974, employment in the Canadian electronic industry fell to 62,639 in 1977. By 1980, employment had recovered somewhat to 65,323. A reduction of 3000 to 4000 jobs has occurred in each of the Radio and Television, Communications and Components, and Office Machinery segments. Employment in the Instruments segment was about the same during 1974 as during 1980.

With about two-thirds of the industry employment in Ontario, the provincial trend has been nearly parallel to the national trend. In 1978, the electronic industry employed 43,000 people in Ontario which represents about 5 per cent of total employment in manufacturing in the province.

In recent years there has been a trend to locating labour-intensive manufacturing and assembly operations in low-wage countries. In developed countries, the electronic industry has become a key employer of highly-skilled manpower.

## Location of the Industry

Table 3 shows that 72 per cent of the value of shipments of electronic products come from Ontario plants and 68 per cent of the industry employment is in Ontario. The portion of each industry segment that is located in Ontario has fluctuated somewhat in recent years, but overall Ontario's share of the industry has remained stable.

The Communications and Components segment is the largest component of the Ontario industry. With shipments of $986 million and employment of 23,899 in 1978, it is about twice the size of the next largest segment--Instruments.

Direct purchases of products by governments often play a key role in establishing new technology and new companies. For example, the Government of Ontario's recently announced decision to purchase 2000 Telidon terminals will not only provide an opportunity to demonstrate the feasibility of a new product, but will also provide enough orders to lower production costs. These two elements are critical to Telidon's acceptance in world markets and to ensure that Canadian companies are capable of supplying the markets.

In an industry as dependent on technology as electronics, the availability of R & D funds is critical to its growth and development. In the United

States, the military and aerospace programs have played key roles in computer and integrated circuit developments. Other countries, such as Canada, that do not have large-scale military and aerospace programs, promote R & D through grants and tax incentives.

For countries with a large domestic market, protectionist measures, usually in the form of non-tariff barriers, can provide a captive market to domestic producers. Some countries have used such an approach to develop a strong industry capable of competing in world markets. The Canadian market is relatively free of trade barriers and, given the small size of the market, it is doubtful that protectionist measures would provide any long-term benefits to the domestic industry. However, Canada does have relatively easy access to the world's largest market--the United States.

## Major Trading Partners

The United States is Canada's largest trading partner in electronic products. The leading countries of destination of exports and leading supplier countries of imports are shown in Table 4 and Table 5, respectively. The United States accounted for 64 per cent of Canada's exports, the United Kingdom took 4.7 per cent and the rest went to a number of countries, none of which accounted for more than 2 per cent of the total.

Canada imported $3.8 billion dollars of electronic products from the United States in 1980, which was 78 per cent of total imports of such products. Japan supplied a further 10 per cent ($489 million) and the remainder came from several other European and Asian countries. In recent years the share of imports from industrialized countries has been declining and the share of imports from some newly industrializing areas, such as Taiwan and Puerto Rico, has been increasing.

## Industry Performance

The performance of the industry, between 1974 and 1980, is summarized in Table 6.

While the average annual growth rate of shipments has been a respectable 6.3 per cent, in real terms, the domestic market has grown at a faster rate. The increase in demand has been met largely by imports which have grown, on average, at 13.5 per cent per year. As a result, the trade deficit (in constant 1971 dollars) almost doubled from $993 million in 1974 to $1886 million in 1980.

In the last three to four years, shipments have been growing at a faster rate than the long-run average and there are signs that the gap between the growth rates of shipments and the domestic market is narrowing. However, since the base size of the domestic market is considerably larger than the base volume of shipments, the absolute size of the trade deficit is expected to continue to rise for the foreseeable future.

Due to increased rationalization of the industry and other factors, exports have grown at an average annual rate of over 16 per cent. The productivity of the industry is improving as shown in Figure 2. Shipments per employee (in constant dollars) increased about 41 per cent from 1977 to 1980.

## Foreign Ownership

As shown in Table 7, over 67 per cent of the electronic industry was foreign-owned, as of 1976. If the Communications and Components segment, which is about 55 per cent Canadian owned, is subtracted from the total, foreign ownership would exceed 90 per cent. According to Department of Industry, Trade and Commerce figures (9), 72 of the 100 largest firms operating in Canada are foreign-controlled. Of these, 20 per cent account for 55 per cent of industry sales.

The high degree of foreign ownership has been a significant factor in the development of the industry. Many of the foreign-controlled firms do not have the capability or mandate to develop new domestic or international markets. Therefore, the ability of the domestic industry to expand production and reduce the trade deficit is constrained.

Many of the Canadian-owned firms are growing very rapidly. Annual growth rates of 50 to 100 per cent are not uncommon, but they are growing from a rather small base. Thus, while Canadian-owned companies will play an increasingly greater role, a high degree of foreign ownership will continue to be a feature of the industry.

## Research and Development Expenditures

The ability to acquire state-of-the-art technology is critical for companies to be competitive in world markets. Technology can be acquired through licensing agreements, transfer from a parent company, and through in-house research and development programs.

In 1980, the electrical and electronic products industry spent $168 million on research and development, or about 3.6 per cent of gross sales (10). While this is more than four times the 0.8 per cent of sales for all manufacturing, many electronics companies spend much more on R & D than the industry average.

A subsidiary of Northern Telecom and Bell Canada, Bell-Northern Research is the largest industrial research organization in Canada. In 1980, Northern Telecom spent $140.9 million dollars, or 6.9 per cent of total revenues, on R & D. Of this, $80.6 million was spent at Bell-Northern Research and the remainder at Northern Telecom's manufacturing operations.

The smaller Canadian-owned companies typically spend 10 per cent or more of their total revenues on R & D. Thus, while the Canadian industry's average of 3.6 per cent of sales is small in comparison to the United States industry's average of 9 per cent, R & D spending of some of the Canadian-owned companies is keeping pace with their United States and other foreign competitors. This is no doubt one of the major factors in the rapid growth of these companies.

References

(1) STATSCAN Cat. No.'s 31-001, 65-007, 65-004.

(2) STATSCAN Cat. No.'s 31-203, 31-001, 72-002.

(3) STATSCAN Cat. No. 31-203.

(4) STATSCAN Cat. No. 65-004.

(5) STATSCAN Cat. No. 65-007.

(6) STATSCAN Cat. No.'s 31-203, 31-001, 65-007, 65-004, 62-011.

(7) STATSCAN Cat. No.'s 31-203; 31-001.

(8) STATSCAN Cat. No. 31-401.

(9) "Canada's Electronics Industry", Department of Industry, Trade and Commerce, Electrical and Electronics Branch, July, 1980.

(10) STATSCAN Cat. No. 31-212.

Table 1

## DOMESTIC MARKET AND FOREIGN TRADE — 1980

| SIC No. | PRODUCT DESCRIPTION | ($ Million) Shipments | Net Imports | Exports | ADM* | Trade Balance | Net Imports as % of ADM | Exports as % of Shipments | Shipments as % of ADM |
|---|---|---|---|---|---|---|---|---|---|
| 318 | Office Machines | 795 | 1709 | 739 | 1765 | (970) | 97 | 93 | 45 |
| 334 | Radio and Television | 250 | 531 | 68 | 713 | (463) | 74 | 24 | 35 |
| 335 | Communications and Components | 2319 | 1594 | 1041 | 2872 | (553) | 56 | 45 | 81 |
| 3911 | Instruments | 924 | 699 | 148 | 1475 | (551) | 47 | 16 | 63 |
| | TOTAL | 4288 | 4533 | 1996 | 6825 | (2537) | 66 | 47 | 63 |

Source: ( 1 )

* Apparent Domestic Market

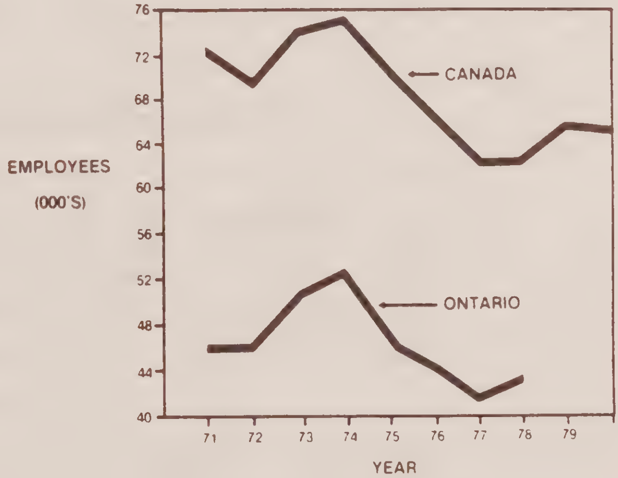
Table 2

## NUMBER OF EMPLOYEES: 1971 — 1980

| Year | EMPLOYEES CANADA | ONTARIO | ONTARIO AS % OFCANADA |
|---|---|---|---|
| 1971 | 72264 | 45952 | 64% |
| 1972 | 69435 | 45945 | 66% |
| 1973 | 74545 | 51494 | 69% |
| 1974 | 75457 | 52962 | 70% |
| 1975 | 70651 | 47040 | 67% |
| 1976 | 66799 | 44616 | 67% |
| 1977 | 62639 | 41735 | 67% |
| 1978 | 63347 | 42996 | 68% |
| 1979 | 65872 | N.A. | |
| 1980 | 65323 | N.A. | |

Source: ( 2 )

Figure 1




Source ( 2 )

Table 3

## LOCATION AND RELATIVE SIZE OF THE INDUSTRY BY SEGMENT — 1978

| SIC No. | PRODUCT DESCRIPTION | Shipments ($ Million) CANADA | ONTARIO | Ontario as % of Canada | Employees CANADA | ONTARIO | Ontario as % of Canada |
|---|---|---|---|---|---|---|---|
| 318 | Office Machines | 547 | 389 | 53% | 9629 | 5886 | 61% |
| 334 | Radio and Television | 172 | 156 | 91% | 2332 | 2090 | 90% |
| 335 | Communications and Components | 1532 | 986 | 64% | 37895 | 23899 | 63% |
| 3911 | Instruments | 618 | 536 | 87% | 13491 | 11121 | 82% |
| | TOTAL | 2869 | 2067 | 72% | 63347 | 42996 | 68% |

Source: ( 3 )

Table 4

## EXPORTS OF ELECTRONICS PRODUCTS — 1980

| Industry Grouping | Total Exports 1980 | USA Value — M$ | — % | U.K. Value — M$ | — % | Netherlands Value — M$ | — % | W. Germany Value — M$ | — % | France Value — M$ | — % | Sweden Value — M$ | — % | Others Value — M$ | — % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Electronics Industry | 1996 | 1276 | 63.9 | 93 | 4.7 | 40 | 2.0 | 40 | 2.0 | 40 | 2.0 | 29 | 1.5 | 478 | 23.9 |
| S.I.C | | | | | | | | | | | | | | | |
| 334 — Radio and Television | 68 | 50 | 73.5 | 13 | 19.1 | — | — | — | — | — | — | — | — | 5 | 7.4 |
| 335 — Communications | 730 | 456 | 62.5 | 28 | 3.8 | 9 | 1.2 | 9 | 1.2 | 10 | 1.4 | 8 | 1.1 | 210 | 28.8 |
| 335 — Components | 311 | 207 | 66.6 | 14 | 4.5 | 1 | 0.3 | 15 | 4.8 | 9 | 2.9 | 2 | 0.6 | 63 | 20.3 |
| 318 — Office Machines | 739 | 491 | 66.4 | 31 | 4.2 | 27 | 3.7 | 13 | 1.7 | 20 | 2.7 | 19 | 2.6 | 138 | 18.7 |
| 3911 — Instruments | 148 | 72 | 48.7 | 7 | 4.7 | 3 | 2.0 | 3 | 2.0 | 1 | 0.7 | 1 | 0.7 | 61 | 41.2 |

Source: ( 4 )

Table 5

## IMPORTS OF ELECTRONIC PRODUCTS — 1980

| Industry Grouping | Total Imports 1980 | USA Value — M$ | — % | Japan Value — M$ | — % | Taiwan Value — M$ | — % | U.K. Value — M$ | — % | South Korea Value — M$ | — % | W. Germany Value — M$ | — % | Others Value — M$ | — % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Electronics Industry | 4853 | 3801 | 78.3 | 489 | 10.1 | 91 | 1.9 | 82 | 1.7 | 67 | 1.4 | 57 | 1.1 | 266 | 5.5 |
| S.I.C. | | | | | | | | | | | | | | | |
| 334 — Radio and Television | 536 | 200 | 37.3 | 178 | 33.2 | 51 | 9.5 | 1 | 0.2 | 55 | 10.3 | 2 | 0.4 | 49 | 9.1 |
| 335 — Communications | 454 | 362 | 79.7 | 39 | 8.6 | 4 | 0.9 | 18 | 4.0 | 4 | 0.9 | 4 | 0.9 | 23 | 5.0 |
| 335 — Components | 1237 | 921 | 74.4 | 146 | 11.8 | 33 | 2.7 | 26 | 2.1 | 7 | 0.6 | 21 | 1.7 | 83 | 6.7 |
| 318 — Office Machines | 1896 | 1704 | 89.9 | 66 | 3.5 | 3 | 0.2 | 21 | 1.1 | — | — | 14 | 0.7 | 88 | 4.6 |
| 3311 — Instruments | 730 | 614 | 84.1 | 60 | 8.2 | — | — | 16 | 2.2 | 1 | 0.1 | 16 | 2.2 | 23 | 3.2 |

Source: ( 5 )

Table 6

## INDUSTRY PERFORMANCE IN CONSTANT 1971 $

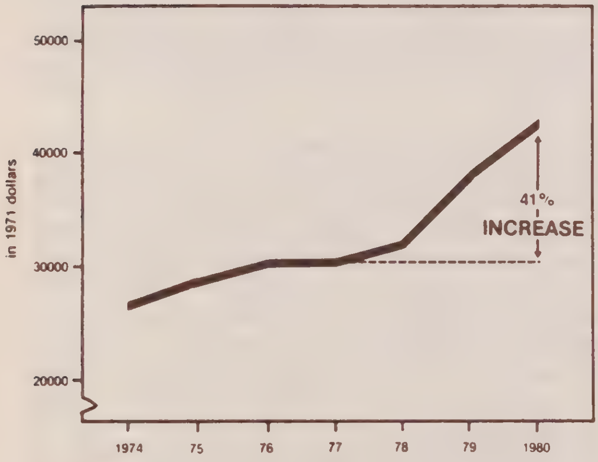
| | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1980 | AAGR* |
|---|---|---|---|---|---|---|---|---|
| Shipments | 1986 | 2028 | 2021 | 1898 | 2030 | 2519 | 2798 | 6.3 % |
| Net Imports | 1595 | 1507 | 1851 | 1846 | 2286 | 2706 | 3298 | 13.5% |
| Exports | 602 | 644 | 786 | 700 | 921 | 1215 | 1412 | 16.3% |
| Apparent Domestic Market (ADM) | 2979 | 2891 | 3086 | 3044 | 3395 | 4010 | 4684 | 8.1% |
| Trade Balance | (993) | (863) | (1065) | (1146) | (1365) | (1491) | (1886) | 12.1% |
| Shipments as % of ADM | 67% | 70% | 65% | 62% | 60% | 63% | 60% | |

Source: ( 6 )

* Average Annual Growth Rate

Figure 2

SHIPMENTS PER EMPLOYEE — (Constant 1971 dollars)




Source: ( 7 )

Table 7

## FOREIGN OWNERSHIP — 1976

| SIC No. | PRODUCT DESCRIPTION | % Value of Shipments |
|---|---|---|
| 318 | Office Machines | 92.6 |
| 334 | Radio and Television | 88.1 |
| 335 | Communications and Components | 54.9 |
| 3911 | Instruments | 89.4 |
| | TOTAL | 67.3 |

Source: ( 8 )

## MICROELECTRONICS: THE CORE TECHNOLOGY

### Technological Developments

An important field of physical science has developed around the activity and control of electrons. The electronic industry is centered around this science. As our understanding of the physics of matter and materials has progressed, the electronic industry has continued to grow by converting this knowledge into practical use.

Electronics as an industry has only developed since the beginning of the twentieth century. By the end of the 1940s the structure of the industry consisted of three interrelated levels: the manufacture of components, equipment and systems. Some companies specialized in components, others in equipment and others in systems, and some large companies were involved at all levels.

The earlier products were principally based on electron tube technology and electromechanical devices. The major markets were in the fields of communications, navigation and control; and the requirements in these markets were generally related to some national need or purpose. In industrially developed countries there was, therefore, an apparent striving for a self-sufficient industrial structure, i.e., production of components, equipment and systems was being pursued and encouraged within each country.

A major technological breakthrough took place in 1948. The Bell Telephone Laboratories proved the practicality of the transistor which was a new device capable of performing some of the functions hitherto performed by electron tubes (such as amplification, switching and rectification).

In the electron tube a stream of electrons flows between two or more electrodes through a vacuum sealed within a glass or metal enclosure. Manufacture of electron tubes involves a number of individual parts which have to be assembled for each tube, i.e., for each control function. Even with very large-scale production, it therefore appeared that the cost per function would not likely be reduced below about 10 to 20 cents each.

In a transistor, however, the current flows between and through regions/junctions in a solid material called a semiconductor. The control characteristics of the transistor are produced by starting with a wafer of purified material, such as germanium or silicon, and by using a photolithographic process diffusing other materials, such as antimony or indium, into carefully controlled regions of the host material. In fact, several transistor elements can be made on each wafer as it passes through the process. The wafer is subsequently separated into its individual transistor chips which are then mounted in holders or packages to be used as controlling or "active" components in various types of electronic circuits. It was soon realized that the manufacture of transistor chips was basically process intensive, that is, the number of transistors per wafer could be increased by improving the photolithographic resolution and diffusion processes. As such improvements were developed it became possible to obtain yields of several hundred transistor chips at each pass through the process.

However, while the cost of the transistor chips was reduced, these chips still had to be mounted in individual packages to protect the chips and to facilitate interconnections with other passive components in electronic circuits. These assembly steps were relatively labour intensive. To reduce cost, it became common to have such assembly operations done in countries where labour costs were only a fraction of that in North America and European countries, e.g., in the Far East. In fact, Japan seized the opportunity during this period to accelerate the development of their electronic industry. Japanese firms initially became the production arm of U.S. companies in the consumer electronic field. However, over a period of time the Japanese improved the products and engineered new ones, and their electronic industry evolved into a major supplier of semiconductor-based consumer products to the world.

Meanwhile, the semiconductor technology in the United States progressed and by the early 1960s simple, but complete, electronic circuits were produced in semiconductor chip form. Since these circuits not only included the control functions (i.e., active elements or transistors) but also the equivalent of passive component functions, the circuits were called integrated circuits (ICs). As the integrated circuit technology has evolved, the number of circuit elements per chip has continued to increase as shown in Figure 1. The number of components producible per chip has generally doubled every year since the early 1960s. It is expected that this trend will continue.

As mentioned previously, each chip, whatever its complexity, must be mounted in its individual package for handling and to facilitate connections externally, i.e., it becomes a component* of a larger entity or piece of equipment (e.g., computer, telephone, audio amplifier). And since many of the functional interconnections are part of the chip manufacturing process it does not cost much more to package a complex chip than a single function transistor chip. It can be seen that the cost reductions resulting from the process-intensive semiconductor chip technology carries forward to the price of the end-equipment.

It has been common for the price of each new generation of semiconductor components to decline about 25 per cent per year after original introduction. This is shown in a normalized form in Figure 2 for a type of transistor, a type of integrated circuit memory, and the average integrated circuit.

*The expression "component" is used within the electronics industry in a very broad sense, i.e., it is applied to simple, discrete function devices, to very complex, multifunction integrated circuits of various types, as well as to assemblies of electrical and mechanical parts used in equipment.

There are several important aspects to this graph. One is that the cost per electronic function keeps on decreasing with time with no apparent lower limit yet observable. Another aspect is that a particular complex combination of electronic functions that might not be economically viable at a certain point in time will be practical some time in the future. A corollary to this is that the market life-cycle of many end-products becomes shorter, and/or that the first manufacturer on the market with a new product has a cost advantage and, in addition, might benefit from a "capture effect" by being the first on the market. It also illustrates the importance of close coupling between the state-of-the-art in semiconductor technology and the equipment manufacturers.

In addition to the above mentioned improvements in cost, other benefits resulting from semiconductor technology are equally impressive. There is an improvement in reliability, a decrease in size and weight, less power is required, and the possible speed of operation has increased in proportion to the decrease in size. Taken together these factors open up endless possibilities for applications of microelectronic products, in such fields as telecommunications, industrial and commercial areas, and in consumer products. Microelectronics* is a core technology.

The number of possible mutations and permutations of electronic functions is only limited by one's imagination. To date, thousands of different types of semiconductor devices have already been produced to satisfy special operational requirements of the various electronic equipment. Each type of device is designed to provide and/or enhance some specific function or combination of functions (examples are amplification, metrification, switching, logic, storage of information, processing of data, converting light into electric signals or vice versa). There are several process technologies utilized with names such as Bipolar (i.e., the operation involves the interaction of both positive and negative charges), MOS (metal-oxide - semiconductor) and numerous variations of these approaches each of which yields or optimizes different device characteristics.

The impetus to develop new microelectronic devices often comes from the electronic equipment manufacturer who wants to attain some performance or cost objective. The microcircuits thus produced are often referred to as custom integrated circuits and, depending on the wishes of the equipment manufacturer, may remain proprietary devices, i.e., they can only be produced for him. Development costs, which may be several hundred thousand dollars, are then borne by the customer. Production runs may vary from hundreds to millions of units.

However, to design a special, dedicated integrated circuit from the ground up is both costly and time consuming (e.g., it might take 12 to 24 months to design and get into early production). In response to the need for custom circuits, an approach referred to as the master-slice or uncommitted array

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*A common definition of "microelectronics" is the study, design and use of devices that depend upon the conduction of electricity through semiconductors and which are made to extremely small dimensions.

technique is gaining in use. A large number of functions are provided on a chip but the process is stopped short of the final interconnections of these elements. The final interconnections can be added to suit a number of different requirements at a substantial saving in cost and a much reduced turn-around time. Success depends upon close cooperation between semiconductor manufacturer and the customer. The latter have design cognizance, but also the risk.

While custom integrated circuits are very important to the electronic equipment manufacturers, the major volume in units and dollar sales for the semiconductor industry itself comes from standard components. These are devices designed and produced by semiconductor manufacturers, based on their own market analyses to fulfill a broad range of applications. When developed, such devices often involve extending the leading edge of the process technology and might involve millions of dollars in development costs and years to complete. Examples of such circuits are progressively complex microelectronic memories, microprocessors and microcomputers. Usually, very large production volumes are required to amortize the development costs and investments in production facilities.

As the complexity of a circuit increases the areas of applications become more limited. The development of programmable microcircuits has helped overcome this hurdle. For these devices, sequences of instructions can be imparted to the microprocessor to tailor its characteristics subsequent to the physical manufacture of the device. In some cases, these instructions are of a permanent nature; in other types of circuits it is possible to re-program the device later on should this be desired. Programmable microelectronics is a very powerful advance in the technology.

The more successful products are commonly crosslicenced for manufacture by a few other semiconductor producers in order to strengthen the market position. (Since millions of units of each type might eventually be produced at very low unit prices, standard devices are sometimes referred to as "jelly bean" components).

The dynamic growth and impact of microelectronics as a core technology is illustrated in Figures 3 through 9. The growth of the world and U.S. semiconductor markets is shown in Figure 3. By 1984 it is expected that the world market for semiconductor devices will exceed $20 billion. Although solid state devices first found major applications in government and military equipment, the major growth will come from their use in consumer and industrial products and in data processing equipment of all types as indicated in Figure 4.

The United States is the world's leading producer of microelectronics and of electronic products. It also represents the largest single market for both. Statistics and trends in the United States are therefore valid industry indicators. Figure 5 shows the growing importance of integrated circuits in relation to other semiconductor products.
The traditional building blocks of the overall electronics industry are electronics components. The growth of all types of components is shown in Figure 6. Figure 7 illustrates the extent to which semiconductors are capturing a larger and larger share of the electronic components market, and Figure 8 shows that semiconductors already account for about 7% of the electronics equipment value. By 1984, they will account for nearly 10% of the electronic industry shipments in the U.S.

The pervasiveness of the electronics industry is evident from the indicated areas of application, Figure 9. In particular, it will be noted that computers, office machinery and other industrial and commercial equipment are projected to grow the fastest. These are important areas as they affect the productivity and competitiveness of most manufacturing industries, service industries, and other forms of business.

There is a growing perception throughout the world that the impact of micro-electronics has only barely begun. There is also a growing realization that this technology will continue to impact industry, business and personal domains wherever located, and with little or no regard for regional electronic industry participation, i.e., the technology offers improvements that will be utilized by all sectors. If the regional electronic industry is given a climate in which to grow and contribute - so much the better. If, on the other hand, the realities of this international competition are not recognized and are only given token support, then continual deficits and export of high-quality jobs will result.

## International Perspective

North America, Western Europe and Japan are the major producers and consumers of electronic products. Together these countries produce over 85 percent of total free world output and account for over 80 per cent of the electronic equipment market which in 1980 reached an estimated US $180 billion.

During the last decade, electronics has been one of the fastest expanding sectors throughout the world with a growth rate of more than 10 per cent per annum. A publication from OECD (5) suggests that in some countries, the share of this sector in total industrial production is approaching that of the car industry and that electronics will grow substantially faster than the manufacturing industry as a whole. In one scenario, it is visualized that the annual growth rate of the electronic industry world-wide up until 1990 might be around 8 per cent compared with approximately 5 per cent for the whole of the manufacturing industry.

One of the essential factors in the electronic industry is the rapid evolution that is taking place in electronic components, and particularly in semiconductor devices and in software. The free-world semiconductor industry in 1980 shipped about $14 billion (of this about $10 billion were integrated circuits). This output was critical to the production of about $180 billion in electronic goods and an equal or larger amount for services provided in the data processing and communications industries.

The electronic industry is truly international in character and, because it is knowledge-intensive rather than raw-material intensive, the industry exhibits considerable mobility and will locate where favourable conditions exist or are being created. An example is the previously mentioned labour-intensive packaging and assembly operations being done in areas where labour costs are low. Another good illustration is perhaps reflected in an

advertisement (6) by the Scottish Development Agency under the heading "Last year, 200 American Companies grossed $4.5 billion in one electronically-minded country. Read how they made it." (The country referred to is Scotland, of course).

The international character of the electronics industry is also evident in semiconductors and integrated circuits. The major consumption of integrated circuits is in the United States which, in 1980, represented about 47 per cent of total world consumption. Western Europe and Japan accounted for about 20 per cent and 19 per cent respectively, and the rest of the world, including the Eastern Bloc, for an estimated 13 per cent. (See Table 1).

Similarly, U.S.-based firms (and their subsidiaries) accounted for an estimated 71 per cent of world production of integrated circuits in 1980. Japan's share is about 16 per cent and Western Europe about 6 per cent (see Table 2). It will also be noted that the indicated U.S. production is made up of two main entries: (1) products sold on the open market, and (2), so-called captive products. The latter reflects an increasing trend of equipment manufacturers to establish and/or expand their in-house design and production capability for integrated circuits; it also involves the expansion of semiconductor manufacturers into end, products. This trend towards vertical integration of company activities reflects the growing significance of microelectronics as a core technology and a major element in competitiveness. Most significantly the U.S. captive market is projected to become nearly 50 per cent of its total IC production by 1983-84.

There are many reasons for establishing captive semiconductor capabilities. Concern about security of supply and protection of proprietary know-how and product designs appear to play a major role. Also, the commercial suppliers of standard products usually place their priorities on large-scale production devices and appear less interested in the relatively low quantity production runs of custom ICs for the equipment manufacturers. The economics of having in-house microelectronics capability are not always apparent when viewed in isolation. However, in addition to the factors already mentioned above, the resulting close coupling between the semiconductor technology and the in-house product/systems know-how encourages early and optimized application of microelectronics. In most cases there is now a choice of what to make and what to buy which tends to result in better and more competitive products.

The cost of establishing a new integrated circuit design and manufacturing facility has been increasing rapidly and depends, of course, on the sophistication and production volume of the devices to be made. It would appear that an investment of $50 million or more is required today.(11) This high entry fee has been a deterrent to the establishment of new independent IC-companies. Also, the ownership of a number of independent semiconductor companies in the United States has, during the last 2 to 3 years, been acquired by large corporations who had the financial resources for capital investments. Many of these large corporations are non-American firms who viewed these acquisitions as the most effective entry into this high-technology business.

There is a growing awareness in most developed countries that microelectronics and what may be called the "electronic complex" will be a key element in future industrial development. As such, industry/government collaboration is on the increase in most of these countries. The following excerpts from an address by Basil Beneteau, President of Northern Telecom Canada Ltd., illustrate some of the support for microelectronics in other countries.

> "In terms of recognition of the impact of the information and electronics revolution, it may be enlightening - or frightening - to see what other countries are doing."
>
> "In Britain, for instance, before the 31st of March, 1978, there was little public or political awareness of what the information revolution was doing to the country. Then, the BBC, in its "Horizon" series, broadcast a shattering documentary on the impact of the micro-processing chip, the silicon device I referred to earlier that can undertake all the functions of yesterday's large computers. It was called "The Chips are Down". The following day, Prime Minister Callaghan had it screened at 10 Downing Street. In June of that year, the British government announced a program of massive aid to the microelectronics industry ... some $500 million to be invested over three years in the development of new technology and its application in other industries, and in education and training. The documentary, in a very reasoned tone, described what the new electronics would do to industry and social life, and made it quite clear that if Britain didn't get with it, it would be left behind. Britain decided quickly to get with it."
>
> "Similarly, other nations have focussed their attention on the electronics industry and taken action."
>
> "In Japan, the government has designated the integrated circuit, telecommunications and computer industries as vital to the nation, and therefore targeted for growth. They have a $1 billion program of semiconductor development, and a $250 million program to develop advanced computer software."
>
> "In West Germany, there is a $300 million program to develop integrated circuits, financed jointly by industry and the government."
>
> "In France, a five-year integrated circuit plan has been developed, with the goal of supplying most of the nation's domestic needs. Some $200 million has been committed to this. And in Italy, the government has a $600 million program of direct subsidies and low-cost loans, for use mainly in electronics research and development."

The U.S. has over the years provided substantial financial assistance and encouragement to research and development in the electronic industry through its efforts in military and aerospace programs. For example, in 1978, U.S. Federal electronic expenditures were approximately $18 billion, of which R & D, test and engineering were allocated about $5,440

million for electronics related to defence purposes. It is difficult to identify how much of this sum actually supports development and applications of microelectronics. However, even if only 10 per cent went to such support it would mean around $500 million annually. The U.S. government has also initiated an advanced microelectronic development program, referred to as the VHSI program, (Very High Speed Integration) with a budget of around $200 million.

The above national programs are all addressing, in varying degrees, the following areas of activity:

- R & D on basic semiconductor technology
- Process and production technology
- Establishment and/or expansion of production facilities for semiconductor components
- Microelectronics application in product developments
- Software development
- Education
- Re-training

The Japanese program is generally considered to be the most comprehensive program. Since 1971, over 60 different projects have been undertaken in various identified component related technology areas. In 1977, the Japanese started their three year VLSI (Very Large Scale Integration) program. As a result, Japanese manufacturers are now becoming major competitors in advanced microelectronic components. By the end of 1979 they had captured 22 per cent of the world "open" (i.e., non-captive) semiconductor market and satisfied between 80 and 90 per cent of their own industrial requirements.(2)

About 18 months after the U.K. program was initiated, the British Department of Industry conducted a survey which indicated that 17 per cent of British companies were then using microelectronic techniques in their products vs 5 per cent two years earlier.(8) However, the same survey also showed that the proportion of firms that knew next to nothing about microelectronics had remained unchanged at around 50 per cent since 1977. This lack of awareness is causing some concern among the government officials, even though it is recognized that the actual implementation and results of high-technology programs generally take a number of years of sustained effort.

Canada/Ontario

In the past, most of the semiconductor devices used in Canada have been imported. The primary suppliers have been the semiconductor companies in the United States. In 1980, we imported about $492 million worth of semiconductors of which an estimated $158 million were integrated circuits.(9) The available information on Canadian production in 1980 suggests that only

about $40-$50 million of semiconductors were made here. Exports/re-exports were about $97 million for an apparent consumption of $395 million. However, these statistics might not be accurate since some of the production was for captive markets within vertically integrated companies.

There are four manufacturers of integrated circuits in Canada, all of which have their headquarters in Ontario. These are Linear Technology, Mitel, Northern Telecom and Siltronics. The companies are all Canadian owned. It is interesting to note that there is no foreign-owned manufacturer of semiconductors in Canada even though foreign control in the Canadian electronic industry is over 60 per cent.

The products manufactured by the four companies are all of a specialized nature. Linear Technology specializes in low-voltage micropower audio devices and has gained a world wide reputation for their expertise in this area. As a result, over 90 per cent of the company's production is exported. Sales in 1980 were about $3 million.

Mitel designs and manufactures both microelectronic circuits and telecommunications equipment. Their microelectronic devices were initially designed for specialized applications in the telecommunications field. From this base has developed an advanced and highly competitive range of semiconductor devices and telecommunications products. About one-third of the semiconductor products are used internally and the other two-thirds are sold to other electronic equipment manufacturers in Canada, the U.S. and throughout the world. Mitel's overall sales have been more than doubling annually. The company is also rapidly expanding its LSI and VLSI microelectronic design and production facilities.

Northern Telecom's Canadian production of semiconductor devices has been expanding from about $200,000 in 1975 to about $26 million in 1980. An estimated 95 per cent of these components are made internally for production of telecommunications and office equipment in plants in Canada, the U.S. and overseas. In addition to the in-house production of $26 million worth of semiconductors, the company purchased an estimated $68 million from other companies.

Siltronics is another fastgrowing Canadian company specializing in custom design and fabrication of bipolar integrated circuits. The circuits are usually designed under contract to various equipment manufacturers whose products range from toys, to computers, to industrial and military equipment. The company has recently received substantial contracts for new custom ICs and is planning to expand its facilities. Annual sales in 1980 were $3 million of which almost 90 per cent was exported to clients in the United States. Sales this year are expected to be about $4.5 million for an annual increase of 50 per cent.

From the preceding analysis one will observe that the design and manufacture of semiconductor devices in Canada is gaining momentum. It is worth noting that the major thrust is related to products with application in communications and that the devices are basically custom-designed circuits. The communication industry sub-sector is our strongest electronic sector, the synergy between systems know-how and semiconductor technology is again illustrated. However, overall there is an obvious need to accelerate our semiconductor design and applications capability.

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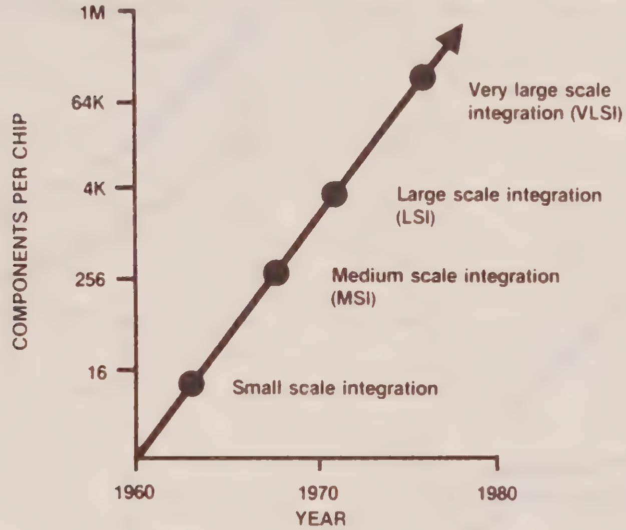
Figure 1

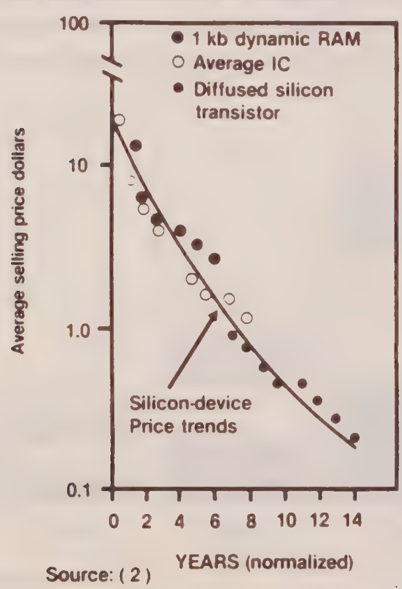
INTEGRATED CIRCUITS
INCREASE IN COMPLEXITY




Source: ( 1 )

Figure 2

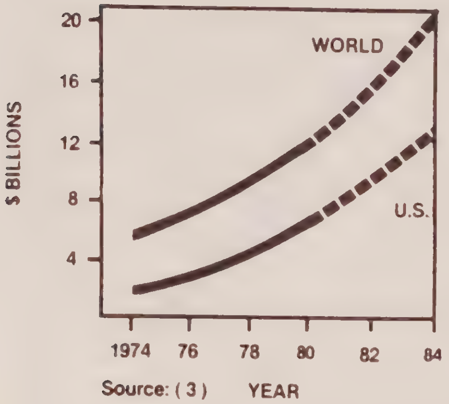
NORMALIZED SILICON DEVICE
PRICE TREND




Source: ( 2 )

Figure 3

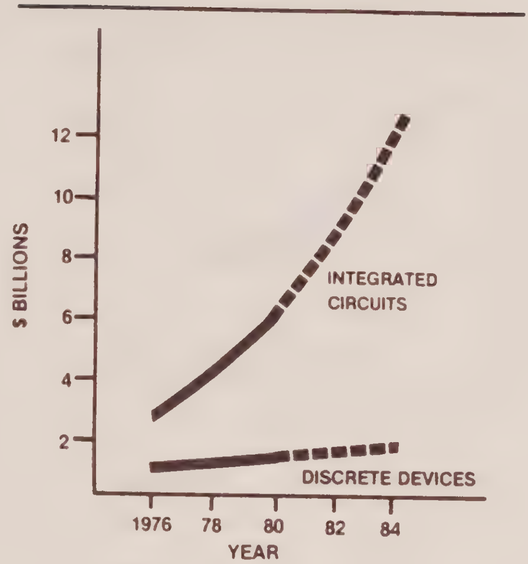
WORLD SEMI-CONDUCTOR MARKET




Source: ( 3 )

Figure 5

U.S. SEMICONDUCTOR MARKET TREND

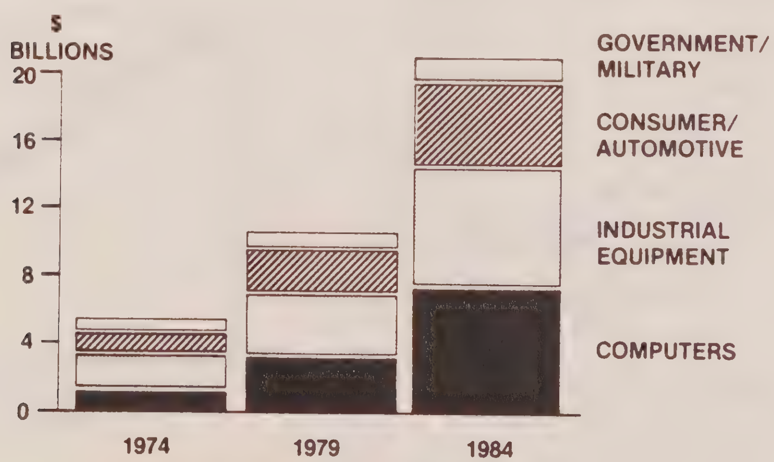



Source: ( 3 )

Figure 4

THE SEMICONDUCTOR'S EVER-WIDENING REACH

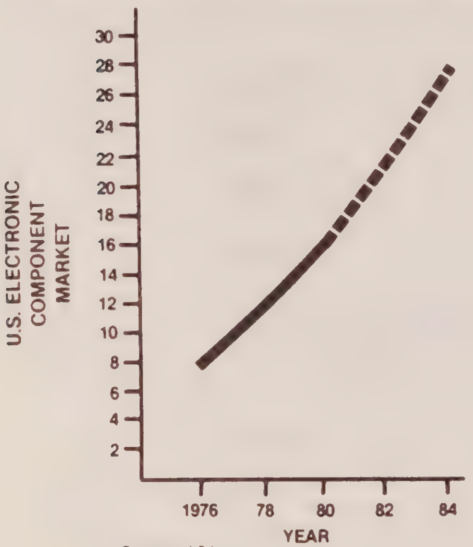
WORLDWIDE SALES ARE DOUBLING EVERY FIVE YEARS




Source: ( 4 )

Figure 6

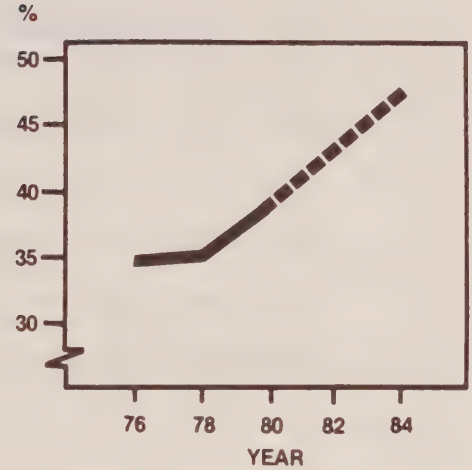
U.S. MARKET FOR ELECTRONIC COMPONENTS




Source: ( 3 )

Fig. 7

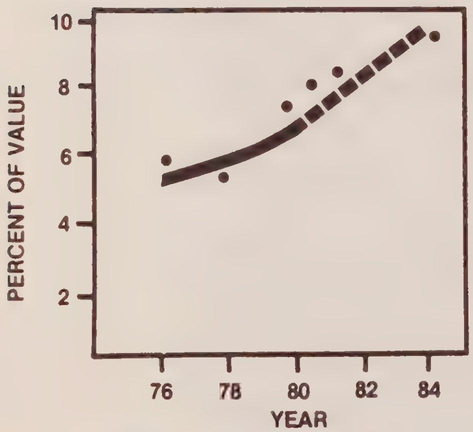
SEMICONDUCTORS AS % OF OVERALL COMPONENT MARKET (U.S.)




Source: ( 3 )

Figure 8

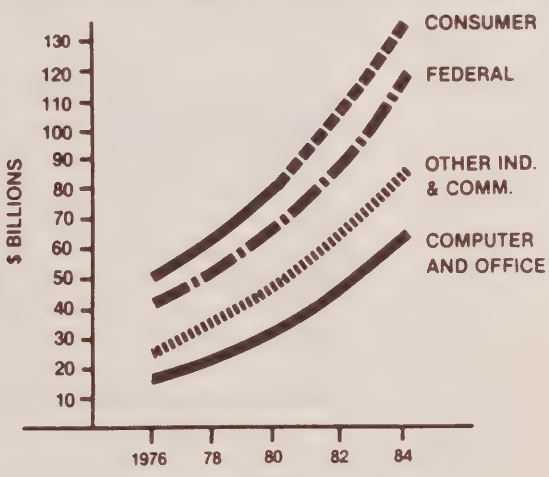
SEMICONDUCTOR AS % OF U.S. EQUIPMENT MARKET




Source: ( 3 )

Figure 9

U.S. ELECTRONIC EQUIPMENT MARKET TREND




Source: ( 3 )

Table 1

## WORLD CONSUMPTION OF INTEGRATED CIRCUITS

| Location | Millions of Dollars 1978 | 1979 | 1980* | 1981* | 1982* |
|---|---|---|---|---|---|
| USA | 3,720 | 4,740 | 5,330 | 6,360 | 7,450 |
| WEST EUROPE | 1,180 | 1,700 | 2,290 | 3,190 | 4,030 |
| JAPAN | 1,150 | 1,560 | 2,140 | 2,630 | 3,310 |
| REST OF THE WORLD | 700 | 950 | 1,500 | 2,040 | 2,500 |
| TOTAL | 6,760 | 8,950 | 11,260 | 14,220 | 17,290 |

* Estimates

Source: ( 6 )

Table: 2

## WORLD PRODUCTION OF INTEGRATED CIRCUITS

| Location | Millions of dollars 1978 | 1979 | 1980* | 1981* | 1982* |
|---|---|---|---|---|---|
| USA | | | | | |
| for OPEN MARKETS | 3,238 | 4,620 | 5,636 | 7,330 | 8,792 |
| for CAPTIVE MARKETS | 1,344 | 1,940 | 2,580 | 3,400 | 4,080 |
| TOTAL USA | 4,582 | 6,560 | 8,216 | 10,730 | 12,872 |
| WEST EUROPE | 453 | 570 | 680 | 750 | 825 |
| JAPAN | 1,195 | 1,470 | 1,850 | 2,220 | 2,660 |
| Rest of WORLD | 482 | 673 | 728 | 943 | 1,127 |
| TOTAL | 6,712 | 9,273 | 11,474 | 14,643 | 17,484 |

* Estimates.

Source: ( 6 )

## SOFTWARE - INTELLIGENCE CONFERRED

### Technical Developments

A much discussed topic is to what extent computers or other machines can be said to possess any form of intelligence. Of course, everyone recognizes that an inanimate, physical piece of equipment is inherently dumb. But, in varying degrees, such electronic "hardware" can be programmed to execute such extensive and varied repertoires of functions that they appear to possess intelligence, hence expressions such as "intelligent electronics" and "artificial intelligence" are sometimes used.

The term software has traditionally been associated with the computer industry. In a general sense, software is the means we use to communicate with the hardware and by which we provide the intelligence that determines and controls what the equipment does. More specifically, software includes computer programs, programming languages, routines and procedures to be followed, program listing and documentation.

In the early days of computers, programs were written in very great detail in a binary logic language (of zeros and ones) that was directly recognizable by the machine. The programs were prepared by individuals with intimate knowledge of electronic circuits and with special aptitude in logic.

It soon became apparent that programming at the "machine language" level was an unduly cumbersome and restrictive process. A further development that began in the mid-1950s was to write the programs in algebraic notations, and this was then translated or compiled into machine language using machine language basic software. From this concept evolved a number of higher-level computer languages such as Fortran, Algol, and many others. High-level languages facilitate programming by bringing the man-machine interface closer to the use of natural languages (e.g., English) so as to encourage the use and application of computers.

However, every type of computer, or computer family, has generally been designed with its own structure and, therefore, has had its own machine language. The various applications programming languages have, as a result, tended to be different from each other. This lack of standardization has had a retarding effect on the rate of diffusion and new application of computer technology. To improve on this situation, the U.S. military, in 1959, encouraged the development of a standard "Common Business Oriented Language" (COBOL), which, like IBM's Fortran, is widely used in connection with today's installed computer base. Also, to facilitate the teaching of programming to a large number of students, an easier, general purpose language was formulated around the mid-1960s. It was called BASIC, an acronym for Beginners All-Purpose Symbolic Instruction Code. BASIC is today commonly used in many of the small and simple personal-type computers.

Until a few years ago, the primary software products were related to computer equipment and systems and consulting. Most software professionals were employed by the computer manufacturers or by software and service bureaus. In effect, software played a supporting role to the data processing industry.

The rapid evolution in semiconductor technology during the 1970s and in particular the advent of programmable integrated circuits, has broadened the requirements for software. Intelligent programmable microcircuits permit standard parts to be used for a large number of different applications. As mentioned, the increased number of functions per microcircuit and the associated decrease in cost per function, has continually reduced the relative cost of the hardware and at the same time allowed greater functional capability. But more complexity requires more software, as illustrated in Figure 1, pertaining to programmable microprocessors.

Many people in the industry feel that an inadequate capability of producing software and the cost of software may constrain the growth of the electronic industry and inhibit the application and utilization of electronics in other industries. The major technical developments in software are therefore directed towards improving the productivity of software generation and towards further development of higher level languages. The major objectives are to make the man-machine interface easier and reduce the need for special training.

The general trend in software continues towards more structured programming languages with the goal that any program can be written using standard software components. This concept is somewhat analagous to the electronic (hardware) component approach being used in equipment design. The U.S. Department of Defence has laid out the objectives for a new programming language called ADA.(12) The goal is to produce a language that not only can be used in all programming environments (e.g., business, scientific) - but that will also set new standards in reliability, readability and maintainability. ADA's adoption as a U.S. and an international standard will likely become a reality within the next two to three years.

Also, the trend towards more sophisticated and powerful hardware/software development tools and systems will continue. Such development aids facilitate program assembly and compilation, microcircuits and equipment emulation, program execution, monitoring, editing and debugging.

In the longer term, futurists project that verbal communications with machines in a natural language will eventually become a reality as a result of developments in voice recognition and synthesis. However, wide-spread use of such systems is not expected to take place for another decade or two.

Importance

The pervasiveness of software was indicated above. It is an increasingly important element in the design and application of microelectronic circuits, and in electronic equipment and systems. Traditionally the electronic industry has been characterized and analysed by the end-products being manufactured, e.g., computers, communications equipment, instrumentation and control. However, the increasing use of digital electronics has tended to merge the technological approach to these end-products. That is, many of these products now include some memory functions and some capability to acquire, analyse or process data, and most equipment involves software at one stage or other.

It is difficult to quantify the overall amount of software required in the design and application of the many different electronic products. But the growing importance of software relative to microprocessor complexity has already been mentioned. Likewise, the importance of software in the computer industry has been, and is, very significant. In addition to the software effort associated with the design of computers, a whole computer software industry has evolved. The "computer service industry" (SIC 853) includes industry activities by those principally engaged in hardware manufacture (SIC 318) and also includes those involved in providing other industrial activities such as software, data systems and data processing services. In this broader context, Figure 2 illustrates the overall trend in the importance of software costs as an element in the overall cost of data processing.

The graph suggests that, on the average, software now accounts for about 80 per cent of the lifetime cost of computer system acquisition and operation and that hardware only accounts for about 20 per cent. The indicated magnitude of software maintenance is based on programs and systems in use up to about 1977. This might improve, however, as modern, less error-prone and more reliable languages and programming techniques gain widespread use. A study by the Rome Air Development Centre (an agency of the U.S. Air Force) indicates that higher-level languages, coupled with structured programming techniques, can more than double software productivity compared to previous approaches (e.g., assembly languages)(3). The study also has determined that the lifecycle costs associated with this software evolution are greatly improved as shown in Figure 3.

Nevertheless, as computers become faster, more programmable and less expensive, more and more applications open up to them. For each new application, new software must be generated. Therefore, the need for software appears open-ended--the more we write, the more we can make these 'intelligent electronics' machines do.

The pervasiveness and the growing importance of software products are illustrated in Figure 4 which depicts the 1980 and projected 1985 markets for four U.S. industry/business segments.

In total, the U.S. market for software products in 1980 was about $2400 million and this is projected to grow at an average annual rate of around 28 per cent and reach about $8400 million in 1985.

It is, therefore, not surprising that an independent computer software and data processing industry has emerged. A wide range of software products are being supplied by independent software companies (i.e., other-than-computer hardware companies) to satisfy the rapidly growing demand. Software products are made up of two distinct segments. Systems software enables the computer/communication systems to perform basic/general functions, and applications software products provides for performing specific application functions. In 1980, U.S. hardware manufacturers supplied an estimated 51 per cent of the systems software, compared to 49 per cent by independent software companies. In applications software however, independent vendors supplied almost 78 per cent of the U.S. market of about $880 million.

In reality, the software industry should perhaps be viewed as a new type of production industry wherein computers represent the means of production and the products are characterized by "intellectual" content as compared to "manual skill" content of older industries. In some ways the "intellectual products" of the software industry are equivalent to the "artistic products" of the film industry. Like many other manufacturing industries, the products of the software and data processing industry are sometimes sold to its customers outright, sometimes sold on a lease basis, and sometimes sold as part of data processing "service" using in-house production machinery (computers and peripheral equipment) and the associated software.

Software is basically information. It is normally contained or stored in various media such as magnetic discs, magnetic tapes, or in semiconductor memories. Shipment or transfer of software can be done by either physically moving the storage media or by transmitting the software information via communications systems. In the latter case the product (software) does not have a physical form and can freely cross national borders without any practical means of assessing value for duty. It also means that software can, in theory, be generated anywhere in the world and sold to and utilized everywhere. In practice, however, there is a certain synergism between the geographical location of computer facilities and software production and job creation.

It is generally recognized and accepted that software has proprietary value. However, neither copyright, patents or any other approach have emerged as a common scheme of protection. A certain amount of protection can be attained by non-disclosure agreements between seller and each user. Also, some part of the program code might be retained by the software producer and provided on a real-time service basis. Large and complex programs enjoy less protection. A better legal protection of software is considered highly desirable.

## International Perspective

The major producers of software are the computer manufacturing firms. The dominant position of the United States in computer hardware also means that the U.S. industry has been the principal supplier of software to the world. Even though considerable effort is taking place in many other countries, there is no reason to believe that the U.S. will relinquish the leading position in either software or hardware in the foreseeable future.

In 1980 the estimated value (5) of all products and services shipped by the U.S. electronic computing equipment industry was about $23 billion. Of this about $6.1 billion was exported, compared to imports of $1 billion. Of equal importance from a software market point of view is the geographic distribution of installed computers where again the U.S. is and will remain the leader (Table 1).

Japan has made considerable progress in design and production of computer equipment, as shown in the following histograph from the 1980 U.S. Industry Outlook, Figure 5.

On the other hand, Japan is generally regarded as being further behind the U.S. in software. To accelerate its software capability, Japanese companies have made purchases and cross-license agreements with U.S., British, Canadian and German companies. Also MITI (Ministry of International Trade and Industry) is encouraging software development by allowing tax benefits for general purpose software. Furthermore, in 1979 a group of seven large Japanese companies started a joint five-year project for software developments. Total government support is expected to be 50 per cent of the estimated $250 million to $350 million effort.(7) The annual growth rate of the Japanese data processing industry is expected to be around 30 per cent per year.

The United Kingdom has had a reputation for excellence in software for a number of years. In addition to the many indigenous companies, a number of large multinational computer companies have established facilities in the U.K. to capitalize on the well-educated work force and the source of trained programmers. The growth of the software industry has been between 20 and 25 per cent annually. The British have made special efforts to break into the U.S. software market and have enjoyed moderate success. Over the years, various forms of support have been provided by the British government. The government has taken holding positions in a number of electronic companies and has provided funding for industry and through educational institutions and technology centres.

France and West Germany are also well represented within the European software industry. Of the leading 30 European software firms in 1977, seven were French. Direct government support does not seem to have been a significant factor in the French software industry development. However, some of the software companies have strong ties with governmental agencies, and major national programs, such as nuclear power and modernization of telecommunications, have provided important stimuli.

In West Germany, companies such as Nixdorf and AEG-Telefunken are considered well advanced in software development and software applications. Development tools and systems are receiving increased attention since it is realized that such computer aided systems can greatly enhance the productivity and reduce the cost of software in the future.

In general, it appears that the Europeans are also placing great emphasis on the future of their software industry. As the chairman of Logica, one of the most successful British software companies, recently said (2):

> "....The strong capability of the U.K., and indeed of Europe in general, in software will be seen as a more and more relevant asset in the whole field of microprocessors and microelectronics...."

In short, the software industry is perceived as a potentially profitable industry in which these countries can participate and in which substantial employment opportunities will be present in the next decade or two.

The worldwide attention to software is understandable when the hardware and software cost relationship in Figure 2 is related to the projections for various types of intelligent electronic hardware as shown in Figures 6, 7, 8.

Andres Grove, President of Intel Inc., foresees the requirements "for more than 1 million software engineers by 1990--a catastrophe." Other projections suggest that the requirement for software specialists by 1990 might exceed 2 million.(3) In comparison to this, the reported number of software people in the U.S. today is between 200,000 and 250,000 and less than 10,000 graduates will enter the labour force annually. The current shortage of good programmers is not likely to improve; to the contrary, on a long-term basis a major gap is developing between the projected demand and the anticipated supply of software specialists. While software generation will be greatly enhanced by development tools and improved programming languages, it would appear that software will be both a major problem and a golden opportunity.

## Canada/Ontario

In 1979 the Canadian computer industry sales revenues were reported at about \$2.8 billion of which hardware accounted for \$1800 million, software products for about \$200 million and processing services for about \$700 million. Software is a fast growing activity to the extent of having become a significant industry subsector in its own right. In addition, software is an important element in the cost of processing services except, in this context, the software is not sold outright.

In 1978, the Canadian computer and service industry included over 700 establishments whose primary business was related to sale or rental of computer hardware (over 30 establishments, 8855 employees) and in providing computer software and services (698 establishments, 13148 employees)(10).

In addition, there were over 450 establishments engaged in providing computer services to the public as a secondary activity. About 95 per cent of the computer industry revenue was provided by the 50 largest companies. Of the leading 15 companies, three are Canadian owned. An estimated 64 per cent of Canadian shipments came from Ontario companies.

A quantitative assessment of Canada's performance compared to other countries is difficult to compile in all aspects of software. Part of this difficulty arises from the fact that up to the early 1970s it was common practice to include software costs as part of equipment costs. Since then, there has been a growing trend to "unbundle" the hardware and software costs. During this transitional period statistics became somewhat questionable. However, an indication of Canada's relative position in software might be deduced from statistics on the independent computer service suppliers (i.e., companies not primarily engaged in computer equipment manufacture). The development of this subsector in the U.S. consisted of around 2600 firms, with 1976 annual sales of around \$5,510 million and a growth rate of around 20 per cent annually.(9) (Based on this growth, the 1978 shipments would be around \$7954 million).

In Canada there were more than 700 independent establishments in 1978 whose shipments were $532 million (10) and whose average growth rate appeared to be around 22 per cent annually. From this, one might observe that the apparent shipments by independent establishments of software and services in the U.S. was about $36 per capita compared to about $24 per capita in Canada. This might be interpreted as meaning that we are about 1-1/2 to 2 years behind the U.S.

It has been suggested (11) that Canada excels in certain areas of software and that we have an opportunity to capitalize further on our expertise in the international market place. Judging from the growth and successes of some Canadian companies this might well be true. However, while such examples indicate that we can be competitive in selected areas of specialization, on a broader basis we might need to expand our level of effort.

For example, British sale of software (only) products in 1978 has been estimated at around 332 million (pounds sterling) (2) or around C$767 million (using 1978 exchange rates). This is about $14 per capita. The Canadian market for software packages (only) in 1978 has been estimated at about $164 million (9) or about $7.50 per capita. While there are so many possible variations in how statistics are complied in a rapidly growing industry, the above comparison would tend to suggest that we have some way to go to develop a broader base in software. Nevertheless, we should note that some Canadian companies are successfully selling their software and services into the U.K. and other markets. The general opinion in industry appears to be that we have to specialize in order to compete and to grow.

So far, any Canadian government assistance for software has been rather limited. Programs or tax measures to specifically encourage software development have not been put in place. At best, support has been provided by accepting software activity as an allowable cost under some government hardware development programs. Much worse, the present application of import duties and taxes to computer equipment indirectly favours foreign sources of software and computer services. On the average, equipment costs account for about 30 per cent of operating costs of Canadian computer service firms, and salaries and employee benefits for about 38 per cent. The application of duty on computers and peripheral equipment (between 10 and 15 per cent) plus federal and provincial sales taxes imposes a 30-35 per cent burden on such equipment cost for companies located in Canada compared to the U.S. This disadvantage not only applies to computer service companies but also applies to in-house central data processing facilities for any business.

The location of the central data processing facility must, for technical reasons, be somewhere with an adequate supply of educated staff, a good and stable source of power and an abundance of high-quality local communications. Canada, and specifically Ontario, can easily meet these requirements, probably as well as, if not better than, any other location in the world.

However, communications technology has advanced rapidly over the past 10 years. Common carriers, value-added carriers and private corporations have all developed techniques for networking which provide versatility and reliability which 10 years ago would have been considered impossible.

One of the principal side effects of this development is the complete freedom it provides to locate the central hub of a network at any location served by the network. The central hub contains the large-scale data processing equipment and conventionally it also contains the development staff. The level of employement at larger central data processing facilities is often 300 or more people.

Faced with the reality of equipment costs and given a choice of locations, several Canadian multinational companies have opted to locate their data processing centres outside Canada.

If the impediments were removed, Ontario could perhaps attract centres serving foreign companies. It is expected that site evaluation will occur in several hundred North American corporations during the next two or three years.

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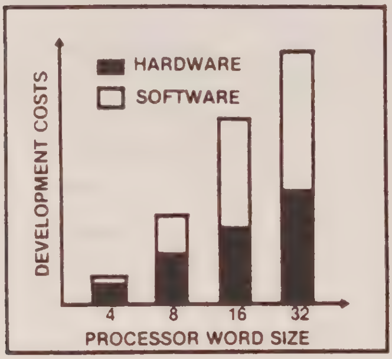
Figure 1

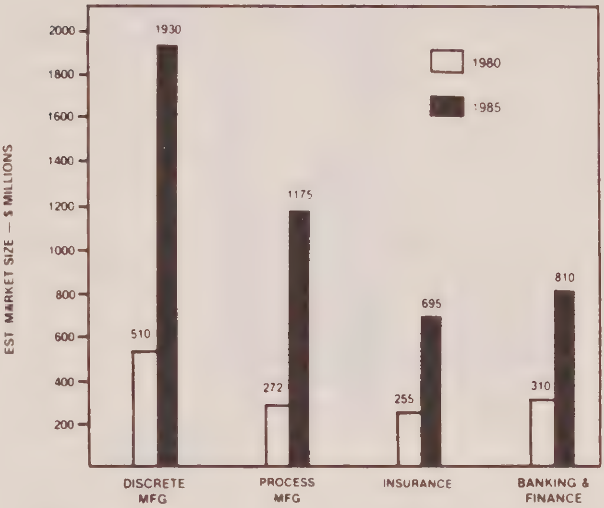
## SKYROCKETING SOFTWARE




Source: ( 1 )

Figure 4

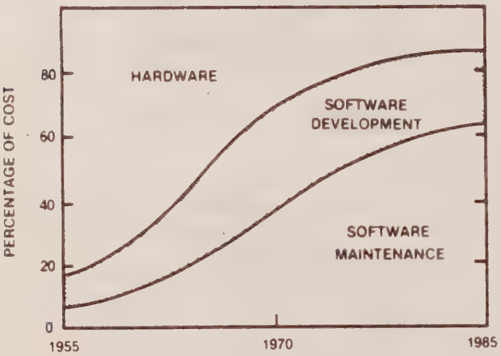
SELECTED U.S. SOFTWARE PRODUCTS MARKETS




Source ( 4 )

Figure 2

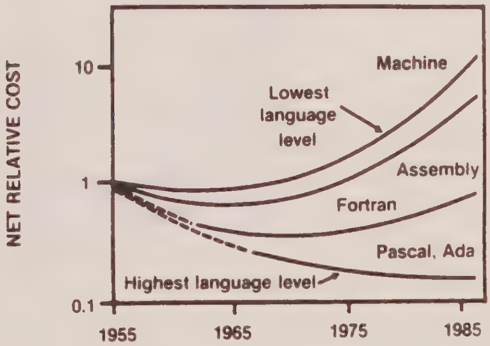
EVOLUTION OF HARDWARE AND SOFTWARE COSTS




Source ( 2 )

Figure 3

## LIFETIME COST OF SOFTWARE SYSTEMS




Source: ( 3 )

Table 1

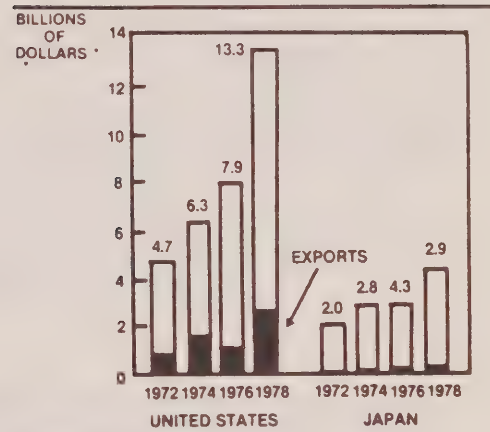
**GEOGRAPHIC DISTRIBUTION OF INSTALLED COMPUTERS (%)**

| COUNTRY/REGIONS | % 1978 | % 1983 | % 1988 |
|---|---|---|---|
| UNITED STATES | 44 | 44 | 40 |
| WESTERN EUROPE | 24 | 25 | 26 |
| JAPAN | 10 | 8 | 8 |
| OTHERS | 22 | 23 | 26 |

Source: ( 6 )

Figure 5

**U.S. AND JAPANESE COMPUTER PRODUCTION AND EXPORTS***



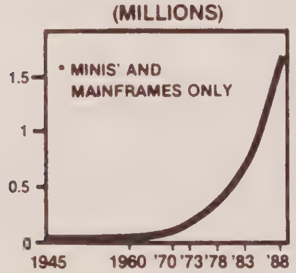

* Excluding Parts

Source: ( 5 )

Figure 6

**ELECTRONIC COMPUTERS IN WORLD**

(MILLIONS)



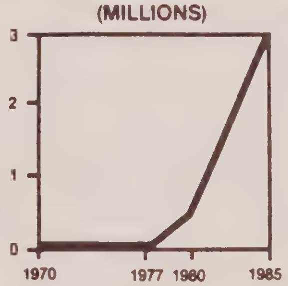

Source: ( 8 )

* ESTIMATE

Figure 7

**INDUSTRIAL MICROCOMPUTERS IN U.S.**

(MILLIONS)

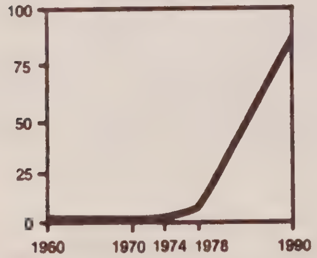



Source: ( 8 )

Figure 8

**ROBOTS IN WORLD**

(THOUSANDS)




Source: ( 8 )

# THE DIFFUSION AND IMPACTS OF MICROELECTRONICS IN CANADA

## BACKGROUND

### Introduction

With a growing body of literature on the diffusion of technology in Canada, a clear picture is emerging which leads to the conclusion that Canada is failing in its rate of technological progress and lags in the application of knowledge and information (1). Recent studies show that Canada is not only slow in the application and diffusion of technology but lags most industrial nations in the utilization of technical innovations, e.g., microelectronic technology (2,3). This lag in the application and diffusion of microelectronic technology has major industrial implications for Canada. In a world characterized by tariff reductions and the emergence of strong industrial competitors, rapid changes in technology have become a prerequisite to the growth and survival of many domestic industries.

One of the conclusions reached by a study commissioned by the Ontario Task Force on Microelectronics (4) stated that the productivity increases induced by the faster diffusion of microelectronic technology will have a substantial impact on output and on the moderation of prices. The study further stated that "There are good economic reasons to favour a public policy stance encouraging microelectronic diffusion. If such a policy were successful, it would constitute a source of economic growth and an anti-inflation tool superior to many others in the monetary and fiscal policy arsenal."

### Nature of Technology Diffusion

The diffusion process is a complex phenomenon, and consequently researchers have always had difficulty accurately distinguishing the cause and effect of factors determining the rate of technological diffusion. Even the dating of the diffusion period for purposes of study usually relies on arbitrary judgment. It is difficult to conceptually determine the period when an innovation is economically possible and then estimate the ultimate equilibrium level of adoption within an industry. Some researchers date the introduction of an innovation when ten per cent of industry's output is produced via the use of the new innovation. But most researchers commonly date the beginning of the diffusion process as the point in time when the first industrial use is made of an innovation. The overall process of technological change can be conceptualized as undergoing three phases: invention, innovation and diffusion. But these stages only serve as a conceptual guide to the technological change process. In fact, the stages usually proceed simultaneously; e.g., R & D frequently continues to be performed in order to modify and improve new products or processes which have already started diffusing throughout the economy.

However technology diffusion is defined, the diffusion pattern for most innovations is described by an "S" shaped curve. As an innovation becomes more widely known and utilized, a higher percentage of potential users will adopt the technology until a saturation level of diffusion has been reached. Most studies attempting to explain the rate and nature of the

diffusion process emphasize demand-pull oriented variables in their analysis (e.g., profitability, firm size, industry growth rates, managerial structure). Supply related characteristics (i.e., technology push variables) such as information availability also play an important role in influencing not only technology adoption patterns but technology diffusion patterns as well. This is particularly true for microelectronic innovation where information about the basic capacity of microprocessor technology is continually changing.

Regardless of which approach is used to analyze the diffusion process, there are a number of broad observations and conclusions that can be drawn from the literature on the nature of technology diffusion (3). These are:

- technology adoption rates vary significantly across countries. There is evidence that Canadian manufacturing and service industries adopt new technology more slowly than other countries in Western Europe and the United States.

- the rate of new technology adoption can vary across firms even within the same industry. This goes against the notion that all firms have access to the same information, as assumed in economic theory. Information about new technology seems to be uneven and costly to acquire.

- most innovations vary in their rate of adoption. Studies show that it is difficult to predict the rate at which specific innovations will be adopted. Economic models suggest that the adoption of new innovations is mainly influenced by factors such as economic advantage over older methods, uncertainty associated with new technology, and the cost of the new commitment.

- large firms adopt and utilize new technology faster than small firms. Large firms, because of their resource base, tend to lead in the early adoption of innovations.

- smaller firms, having adopted an innovation, are quicker to substitute new techniques for older ones.

- rigorous competition leads to higher rates of innovation adoption. Evidence shows that manufacturing innovations are utilized more rapidly in less concentrated industries.

- risk, profit expectation and organizational structure are key factors in the rate of innovation adoption. Managerial sophistication and aggressiveness are seen as important factors in determining the rate of innovation adoption.

The above factors are generally reflected in both manufacturing and service sectors in Canada, e.g., larger firms are quicker to adopt new innovations for both sectors.

The introduction of a microelectronic innovation may very well disrupt the traditional pattern of innovation, adoption and diffusion. Particularly in the manufacturing process, microelectronics offers advantages in terms of cost, size, flexibility and reliability which may eventually alter some of the factors determining the rate of technological adoption by firms regardless of their size. In fact, the adoption and diffusion of microelectronic technology may no longer be a luxury that firms can avoid.

## The Impact of Microelectronic Diffusion

In a study commissioned by the Ontario Task Force on Microelectronics (4), a number of conclusions and observations were reached concerning the nature and impact of microelectronic diffusion. Using an econometric model of the Canadian economy, Chase Econometrics Canada simulated a number of productivity scenarios assuming various rates of microelectronic diffusion throughout the economy. Some of the conclusions of that study are:

- The diffusion of microelectronics in the 1980s is likely to proceed far more slowly than is commonly assumed by proponents of the technology as well as those fearful of its employment effects. We do not question the huge potential of microelectronics, but expect a number of (bottlenecks) (e.g., the lack of skilled programmers and low productivity growth in software development) to slow its productive application over the next ten years.

- The rate of productivity growth induced by microelectronics will lag far behind the rate of change in hardware cost/performance ratios. Moreover, in the aggregate, the contribution to productivity from microelectronics will offset a decline in productivity in the resource sector. To some extent, microelectronics will replace a variety of more diffuse historical sources of productivity growth.

- In all probability, GNP per worker will not increase more than about 1 per cent per annum over the 1980s. It is unlikely that microelectronics will raise the aggregate rate of growth in GNP per worker to the 2.75 per cent average experienced in the 1960s.

- The major effects of an acceleration in the rate of microelectronic diffusion will be an increase in output and a moderation of inflation. The effect on total employment will be minimal. Reductions in unit-labour requirements will be balanced by the additional labour required to meet increased demand.

- Large establishment employment (firms with 20 or more employees) has grown about 50 per cent since 1961, but all establishment employment has nearly doubled. This reflects a shift to a more service-oriented economy dominated by small firms. A higher rate of productivity growth will reinforce this trend, since the proportion of income spent on manufactured goods tends to decline as income per worker increases. There are no signs that the capacity of the service industry to absorb workers is limited.

- There are good economic reasons to favour a public policy stance encouraging microelectronics diffusion. If such a policy were successful, it would constitute a source of economic growth and an anti-inflation tool superior to many others in the monetary and fiscal policy arsenal.

- Part of the gains from productivity increases may have to be allocated to compensate or retrain those adversely affected by technology. However, since the pace of progress in technology is not likely to exceed that achieved in the sixties, inter-industry employment flows are not beyond Canada's historical experience. In consequence, transition problems are expected to be quite manageable.

## HOW CANADA COMPARES IN THE DIFFUSION OF TECHNOLOGY

### Lag Rates in the Introduction of Technology

In an extensive survey study recently undertaken by the Economic Council of Canada concerning the nature of innovation in five Canadian industries, it was found that the lags in introducing innovations into Canada from abroad were generally long. The Economic Council report states that the average time required to initiate a significant innovation developed outside Canada varied among industries - from 5 years in telecommunication equipment to 11 years in smelting and refining. (Table 1).

The study also found that it took, on average, longer to introduce process innovations (8.7 years) than product innovations (7.4 years) into Canadian industries. After an innovation was introduced into a Canadian firm from abroad, it took on average 30 months for a process innovation to be effectively utilized compared to 21 months for a product innovation. Therefore, it took a combined 11 years for Canadian industry to realize a process innovation imported from abroad and approximately 9.5 years for a product innovation.

As already mentioned, a crucial factor in Canada's ability to compete both domestically and internationally is the speed at which important process and product innovations, developed both at home or abroad, are adopted and diffused throughout the economy. It is important to emphasize that, in practice, there does not exist an overall measure of the rate of technological diffusion. Only by gathering evidence on selected technologies does an overall diffusion process evolve.

A study by Prof. S. Globerman examining the rate and nature of technological diffusion in Canada, concluded that Canadian industry not only adopted new technology more slowly in relation to the U.S. and European countries, but also, the diffusion of technology or innovations proceeded more slowly when compared with these countries over similar time periods(3).

Numerically Controlled (NC) Equipment

In the tool and die industry, which has the potential for extensive use of NC equipment, it was found that the percentage of tool and die firms in the U.S. using this technology was consistently higher than in similar Canadian firms throughout the 1960s and early 1970s. The rate of diffusion of NC equipment in the U.S. tool and die industry was approximately four times the rate in the Canadian industry. This finding is still considered generally valid even though the sales of NC machines have increased substantially in Canada according to the Journal of Canadian Machinery and Metalworking. The total number of NC machines has increased to 408 in 1980, up from 233 in 1977. The average number of machines per user has also increased from 2.83 in 1974 to 3.45 in 1980.

The result of a 1981 survey conducted by the Government of Ontario's Ministry of Industry and Tourism and the Ontario Research Foundation,(5), found that about 2 per cent of all machinery in Canada was numerically controlled. In comparison, NC machine tools in the U.S. made up 9 per cent of all metal cutting machine tools in the machinery industries in 1976.

Although not directly related to the issue of technological diffusion, Canada's low levels of NC production and machine tool production in general, is indicative of Canada's lagging technology diffusion in this area. Canadian production of all machine tools, including NC machines, amounted to $110 million in 1979. Imports for the same year were $330 million resulting in a highly negative trade balance of $264 million (Table 2). Import penetration of the domestic market in 1979 was 88 per cent (5).

According to American Machinist, (6), the U.S. shipped nearly $1 billion in NC machines alone in 1979, West Germany, the world's largest NC machine producer, shipped $2.6 billion (U.S.) in 1977 (7). Canada ranks 21st in the world in total machine-tool production (5).

## CAD/CAM

In the important field of computer assisted design and manufacturing (CAD/CAM) there is a growing feeling that Canada lags substantially in the application and diffusion of this technology. Canadian manufacturing industries do not undertake extensive design and research projects which justify large investments in CAD/CAM technology. The world market for CAD is projected to increase from $165 million (U.S.) in 1978 to $2,220 million (U.S.) by 1984. The field is dominated by U.S. producers. Although not directly related to the question of diffusion, it is indicative that only three companies in Canada market computer aided design and drafting systems (5).

## Robotics

In the field of robotics, which is a branch of computer assisted manufacturing (CAM), Canada and Ontario trail all major industrialized nations in both installation and manufacturing. In fact, Canada has no producer of industrial robots to date. According to estimates by the Department of Industry, Trade and Commerce, there are approximately 200 industrial robots throughout the country (the majority used by the auto industry), compared to over 4,000 robots in the U.S. and an estimated 10,000 in Japan. Sweden, which manufactures most of its own industrial robots, uses proportionally more than any other nation (8). Most of the industrial robots used in Canada are imported from Japan and the U.S.

## Office of the Future

There is little doubt that with the advent of the "Office of the Future", there has been a considerable increase in the number of word processors in Canada over the past few years. According to recent estimates (9), there were approximately 18,000 word processors in Canada in 1978 and the same number of computers. A federal government study projects that there will be about 65,000 word processors by 1985 (Table 3). Word processing statistics vary enormously owing to differences of definition. In Europe, Mackintosh Consultants estimated that the total market for automatic typewriters was $60 million in 1976 and will be $131 million in 1981. According to Arthur Cordell, science advisor with the Science Council of Canada, there are currently 100,000 word processors in Western Europe and 400,000 in the U.S. (10). These figures indicate that Canada lags substantially in the diffusion and utilization of office technology in relation to the U.S.

A recent report conducted for the Economic Council of Canada concluded that the utilization of computer technology in Canada, as measured in four broad service areas, was below levels in the U.S. Where data was comparable, the study found that adoption levels of computer automation were higher in the U.S. for hospitals as well as in retailing and wholesaling establishments (e.g., scanning equipment). Only the library sector provided a somewhat different conclusion. Canadian university libraries adopted computer technology at a faster pace than in the U.S. (3).

## MAJOR IMPEDIMENTS TO THE DIFFUSION OF TECHNOLOGY

The principal forces determining the level of technology adoption and the rate of diffusion in Canada can be categorized into three principal areas: economic constraints, delivery system or infrastructure and socio-political considerations. This section will consider only the first two factors.

### Economic Constraints

In the first category, there are five important economic constraints which affect the diffusion of technology. The first deals with the industrial structure of the Canadian economy in general. Empirical studies have shown that the inter-firm diffusion process in Canada is due largely to the "relative advantages" of adopting an innovation. Relative advantage is largely a function of firm size and degree of specialization. A study by the Economic Council (12) found a strong correlation between company size and computer usage. Approximately 50 per cent of businesses, both in manufacturing and services, having 100 employees or less, did not use computer services compared with 13 per cent for those having between 101 and 250 employees. Only one per cent of the firms with more than 250 employees did not use computers in some capacity.

For Canada, shorter manufacturing production runs are seen as making innovations in new production technology unprofitable since overhead development costs are spread over limited and fragmented output volumes.

Further compounding the problem is the extensive level of foreign ownership in Canada's manufacturing industry which, under certain circumstances restricts domestic innovational activity, and limits opportunities for Canadian scientists, engineers and entrepreneurs to develop long-term innovational expertise.

The second economic factor frustrating technology diffusion is the need for firms to amortize old equipment, i.e., make full use of previous investment. A rapid scrapping of obsolete equipment is not economic, particularly in capital-intensive industries. This is perhaps the single most important factor slowing down the diffusion of microelectronic technology. Because of the tremendous financial strain on companies that are forced to automate with microelectronic technology, management usually prefers gradual to sudden upgrading.

The question of compatibility with other systems within a plant or firm also raises problems. Industrial applications of microelectronic devices are limited considerably by the fact that this technology advances at a faster pace than the peripheral sensing and activating technologies.

The above compatibility factor is directly linked to the third factor, hardware and operational costs of the equipment. Even though microelectronic devices are cheap to produce and assemble, the cost of

devices suitable for industrial use can only be reduced by taking advantage of mass production economies, e.g., calculators, watches. Industrial applications tend to be user-specific and often entail costly programming and development costs.

The fourth economic factor is software development. Innovators are finding it increasingly difficult to simplify programming languages for a wide range of users and systems. One problem is that in "idiot-proofing" a system, knowledge of all possible sources of failure needs to be programmed in. This makes cooperation between the innovator and user all the more crucial and costly. The cost of introducing innovations at the product or process level can become prohibitive, especially for small business.

The fifth economic factor is a shortage of skilled, technically trained labour. Education levels of manufacturing personnel have been identified as a major factor affecting diffusion patterns in Canadian industry (2). Canadian manufacturing has traditionally trailed the U.S. in the employment of professional and technical workers. Scientists and engineers made up about 15 per cent of the total manufacturing growth in the professional and technical jobs created between 1965-75 in the U.S. compared to 4 per cent in Canada (1). The Chase Econometric Canada study identifies the shortage of skilled labour as a major impediment or bottleneck, limiting the diffusion of microelectronic technology (4).

Nowhere is the need for skilled workers more acute than in the high technology companies in Canada. A recent survey of such companies indicated that 68 per cent of the firms interviewed had difficulty filling employment requirements. Yet, Canada and Ontario produced proportionally fewer engineers and applied scientists in 1980 than was the case in 1970 (13).

The process of technological upgrading depends on a broad spectrum of scientific and technological activities. In addition to the need for scientists in industrial research, there is also the need for the services of engineers and industrial designers in the innovation process to translate scientific work into industrial products or processes, or to adopt existing technologies to suit the particular needs of firms. These "gatekeepers"" are usually found in large corporations but not always in small firms. European governments are moving fast to solve this problem through promotion, education and retraining, particularly in the engineering professions (14).

## Infrastructure/Delivery System

The effectiveness of the infrastructure is possibly the most critical element in any technology transfer operation. It is the network linking the producers and users of technology. The infrastructure, or delivery system, functions to bring user needs to the attention of funders and research producers, and in turn delivers research results on technology to meet specific user requirements. This infrastructure, or delivery system, can be broadly defined by four categories of participants (15):

° Funder or Entrepreneurs - Those public or private organizations that provide financial resources for the development or adaptation of technologies.

° Research and Development Producers - Those public and private organizations that produce research and development results. These include government laboratories, universities, research institutes and private firms funding research and development activities. Most new or evolving technologies are based on the results of the efforts of those involved in this category.

° Linking Agents or Brokers - Those public or private organizations or individuals that expedite the movement or diffusion of the technology either within or across national boundaries. This category is comprised of functional interest groups, professional organizations, trade associations, consultants and others that work to bring new technologies to bear on existing problems.

° User - The user category can be characterized by including two generally differing participants. These are:

  - Those who benefit directly from the transfer of a given technology (usually the private industrial sector that can utilize the technology to produce more or better goods).

  - Those who benefit indirectly from the transfer (the ultimate user or consumer of the product of the technology).

The infrastructure for technology transfer in the U.S., Japan and Western European industrialized countries are not only similar but highly developed. The U.S., for example, has a sophisticated delivery system serving users at all levels of requirement. Figure 1 illustrates the interplay and linkage between the major players in the technology delivery system in the U.S.

Although a technology transfer infrastructure exists in Canada, it is not as highly developed as that in most industrialized countries. The primary weaknesses of a Canadian technology delivery system lie in the role of governments both as linking agents or brokers and funders.

A recent study of the transfer of technology by the Canadian federal government, stated that:

> "Until recently, technology transfer from the federal laboratories to industry and others has been narrowly perceived. It has been limited to publications of reports, papers in journals, ... and patenting of inventions. Very little attention has been paid to post-invention phase aspects .... The resources, particularly financial ones, required for prototype design, construction product design and pilot plant are sizeable, and a lack of direction and an integrated strategy in obtaining and making use of the resources can result in delays and poor transfers of technology" (16).

The consequences of this result are particularly costly for small to medium-sized high technology companies who are often most receptive to federal technologies.

Most of the western industrial countries and Japan provide, through established channels, massive R & D support in their economies either directly or through military and other programs as in the U.S. Japan subsidizes up to 90 per cent of industrial R & D, West Germany 80 per cent, France and the U.S. 60 per cent, the U.K. 50 per cent, Sweden 45 per cent and Canada 12 per cent. According to Walter F. Light, President of Northern Telecom, it is not surprising that, "the advantages that these levels of government subsidization of R & D given to international competitors can be devastating to Canadian companies operating in world markets..." (17).

Canada, however, does have in place a number of technological assistance programs. The federal government, through the Department of Industry, Trade and Commerce, has taken several initiatives designed to inform Canadian manufacturers of new technology. Some of these programs are:

- New Products Bulletin
- Industrial Research Institutes
- Ten Centres of Advanced Technology.
- NRC's Technical Information Services (TIS)

This last program of the National Research Council (NRC), is the only federal initiative designed to improve industrial productivity through the better utilization of existing technology. The Department of Industry, Trade and Commerce is currently implementing a Special Electronics Fund ($50 million) of which $6 million is slated for six universities over a five year period. One of the objectives of this program is to make available microelectronic technology to small manufacturing firms.

Canada does not have any industrial program equivalent to the European sector-oriented technical centres. The primary objectives of these centres are to provide a link between sources of new technology and industry, as well as assist firms in ways of improving overall productivity.

Another factor weakening Canada's technology transfer infrastructure is the lack of awareness or sophistication among funders of high technology industries. A recent conference in Toronto concerning investment in high technology concluded that, "one of the greatest stumbling blocks in building (high technology industry) in Canada is financing. It's not that there is a shortage of capital; rather, it is a dearth of understanding in both the financial and technological communities of each other's part. Investors tend to be shy of business they don't understand ..." (18).

The studies cited here point to one major deficiency or problem concerning the diffusion of technology: the lack of an efficient formal system to transfer technology from the laboratory to the user, particularly among small firms. The Economic Council's study of innovation technology was encouraged by the level of technical innovation in Canada. Nevertheless, the Council stated; "If we had one concern...(it was) the apparent lack of arm's-length technology sources available to Canadian firms" (11).

The Science Council made the point more strongly:

"The majority of (Canadian-controlled firms) are small and weak in design and marketing capability and their difficulty in remaining technologically up-to-date and efficient seems to be more severe than is the case for small firms in other industrial countries"(1).

## SUMMARY OF FINDINGS

- Studies done on the diffusion of technology indicate Canadian manufacturing, and selected service industries, lag most western industrial nations in the adoption and utilization of micro-electronic based technologies.

- In relation to most industrialized countries, Canadian manufacturing lags in the application and diffusion of NC machines, CAD/CAM, robotics, and industrial equipment. On a per capita basis, Canada trails the U.S. in the utilization of word processor equipment.

- The major impediments to the diffusion of microelectronic technology centre around economic factors, a technology delivery system (or infrastructure) and labour displacement considerations.

- This inability to diffuse product and process innovation quickly will negatively affect Canada's ability to compete domestically and internationally.

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Table 1

## LAGS IN THE INTRODUCTION OF INNOVATIONS INTO CANADA DEVELOPED ABROAD

(PRODUCT AND PROCESS INNOVATIONS)

| | LAG IN YEARS |
|---|---|
| Telecommunications Equipment and Components | 5.5 |
| Electrical Industrial Equipment | 9.1 |
| Plastics components and resins | 7.4 |
| Smelting and Refining | 11.5 |
| Crude Petroleum Exploration and Production | 7.4 |
| Average | 7.8 |

Source: ( 11 )

Table 2

## TRADE AND PRODUCTION DATA OF MAJOR MACHINE TOOL PRODUCING COUNTRIES IN 1979

(INCLUDING N.C. MACHINERY)
US $ MILLIONS

| | GERMANY | USA | USSR | JAPAN | ITALY | UK | FRANCE | EAST GERMANY | SWITZERLAND | POLAND | CANADA |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Production | 4100 | 3890 | 2892 | 2698 | 1354 | 1106 | 913 | 806 | 797 | 685 | 110 |
| Exports | 2460 | 660 | 350 | 1114 | 689 | 473 | 480 | 662 | 677 | 191 | 66 |
| Imports | 541 | 1060 | 800 | 155 | 256 | 601 | 352 | 244 | 139 | 518 | 330 |
| Domestic Market | 2181 | 4290 | 3342 | 1739 | 921 | 1234 | 785 | 388 | 259 | 1012 | 374 |
| Trade Balance | + 1919 | —400 | —450 | + 959 | + 433 | —128 | + 128 | + 418 | + 538 | —327 | —264 |
| Import Penetration % | 25 | 25 | 24 | 9 | 28 | 49 | 45 | 63 | 54 | 51 | 88 |

Source: ( 5 )

Table 3

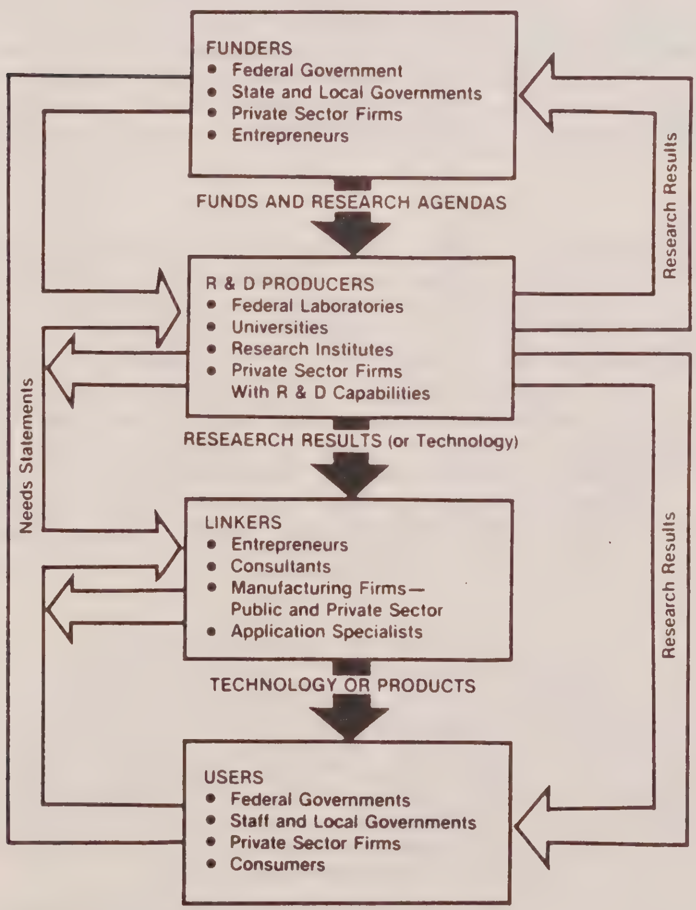
## ESTIMATES OF OFFICE AUTOMATION EQUIPMENT IN CANADA

| ITEM | NUMBER OF UNITS 1978 | PRELIMINARY FORECASTS FOR 1985 |
|---|---|---|
| Business Telephone | 4,500,000 | 6,000,000 |
| Office Typewriters | 800,000 | 960,000 |
| Word Processors | | |
| Non-communicating | 18,000 | 65,000 |
| Communicating | 1,000 | 10,000 |
| Computers | 18,000 | 150,000 |
| Data Terminals | 250,000 | 700,000 |
| Telex, TWX and other | | |
| Message Terminals | 56,000 | 70,000 |
| Facsimile Terminals | 8,000 | 28,000 |
| Photocopy Machines | 300,000 | 450,000 |

Source: ( 9 )

Figure 1

## THE UNITED STATES INFRASTRUCTURE




Source: (15)

## SELECTED ELECTRONIC MARKETS

### OFFICE AUTOMATION

As the importance of the 'knowledge worker' has grown, so has the demand for information - lots of it, in various forms, and it must be readily available. In the past two decades the demand has been largely filled by the ubiquitous photocopy machine. Photocopied documents have become such a pervasive form of business communications that it is difficult to imagine how offices functioned without photocopiers as little as 15 to 20 years ago. The growth of the number of photocopiers in use has been so rapid and their influence on office routines so widespread that it probably can be said that the photocopy machine is as close to a 'revolution in the office' as we are likely to see.

Along with the acceptance of the photocopier has come a flood of paper. Why circulate an original document to a group of people when it is possible to quickly and at little cost provide each of them with a photocopy? Indeed, every time that Xerox or one of its competitors announces a newer, faster, cheaper model, entire forests must quiver at the thought of the sacrifice they will have to make that ever more office workers can be inundated by paper, much of which contains information that is in a form that is not immediately useful. But now to the rescue of the forests comes the micro-processor. Advances in microelectronics technology have led to announcements of a revolution in the office under the banner of 'Office of the Future', 'Automated Office', 'Paperless Office', 'Integrated Electronics Office', and so on.

To most, except possibly our friends the trees, eliminating paper from the office is a secondary consideration. The major benefit of office automation is the timely dissemination of information, in a form that is useful, to decision makers. The following example illustrates the concept. Marketing managers are vitally interested in the share of the market that their products hold in the various regions in which they are sold. In a traditional system, regional offices compile and submit sales data on paper which is then further processed by hand or computer at the head office. By the time market share data arrives on the marketing manager's desk, perhaps three or four months have elapsed. He now knows the regions in which he is gaining or losing market share, but it may be too late to affect the trends that are occurring.

If the process were automated, sales or shipment data would be entered, on a daily basis, via remote terminals. The marketing manager could, at any time, access the data base from a terminal in his office. He could calculate market share for each of the regions, call up another data base containing time series for market shares and then plot the time series data to determine the trend in each region. Or, he may perform any number of statistical or analytic procedures. The point is that automation allows the marketing manager to quickly and easily identify areas of weaknesses in his operations. Having, for example, identified a region in which a product is losing market share, the manager may wish to simulate the effect of several options aimed at reversing the decline. Without leaving the terminal, he accesses a simulation model of the particular market and simulates the

impact of spending an additional $100,000 on advertising, point-of-sale promotion, and hiring additional salesmen, respectively. The results of the simulation show that the best option is to increase advertising. If after further analysis, a decision is made to instruct the regional office to take some action, the instructions can be sent from terminal to terminal, i.e., by electronic mail.

The technology to implement a system such as the one described above has been available for several years. That there are few such systems in operation is due to factors such as cost, lack of awareness, management resistance, and others. The level of automation described in the example could be accomplished, relatively easily, by developing the appropriate software and supporting it on a distributed data processing system.

In a more general sense, the concept of the automated office involves unifying the functions of telecommunications, word processing, data processing and image processing. But moving from concept to products presents major problems. Communications protocols for word processing, text editing, remote business terminals, facsimile transmission, teletype networks and distributed data processing are inconsistent. While the prediction of 'a terminal on every desk' will probably not be realized until the distant future, a display word processor with communications capability begins to resemble the universal office terminal.

When terminals appear on every desk they will probably be part of the telephone. The Bell Canada Displayphone is a move towards a multi-purpose terminal. It would handle both voice and data communications from one desk-top unit, but is at least a year away from being a market reality and many years from being in widespread use.

As an ever increasing portion of western nations' wealth is generated by 'knowledge workers', there is a pressing need to improve the productivity of the office worker. In Canada, the average investment per office worker is about $2,000 and about $35,000 for each factory worker. However, it is expected that this gap will narrow in the future. In order to make any gains in office productivity, expenditures on technology will have to increase dramatically. In the past the most visible products of microelectronic technology have been the computer and the word processor. They have provided large improvements in the productivity of typists and clerks. In the future, purchases of new technology will be aimed, more and more, at making middle and upper management more productive.

Costs will play a significant role in the rate of development of the Integrated Electronic Office. In recent years the cost of employing people has risen at 6 per cent per year. At the same time costs of communications have dropped 11 per cent per year; computer logic 25 per cent per year; and computer memory 40 per cent per year. The figures clearly favour increased spending on office automation.

Apart from the need to improve productivity and reduce costs, advances in technology will accelerate the acceptance of office automation. Areas of current research activity include: voice recognition, graphic displays, telephone technology leading to simple management of digital data, new imaging devices to replace impact print mechanisms, 'smart' copiers, further developments in microform technology and distributed systems based on mini-computers. To tie the parts together, work is underway that will lead to advances in software and standardization of communications protocols.

In short, the future of companies supplying goods and services to the automated office market is bright. The major beneficiaries, at least in the next five to ten years, will be telecommunications companies and those supplying computer hardware and software. The telecommunications market and Canada's position in it is discussed elsewhere. In the section that follows we will look at the markets for computers, peripherals, and word processors. Following that, Canada's position as a manufacturer will be examined and opportunities for the domestic microelectronics industry will be discussed.

## Markets

The computer communications and office equipment market in Canada accounts for more than $10 billion in sales annually. The Canadian market can be broken down as follows:

- ° $3 billion - computer industry; including hardware, software and services.
- ° $6 billion - telecommunications; includes voice and data communications
- ° $1 billion - other office equipment; including business forms and related equipment

Annual growth of the market is about 20 per cent and indications are that the growth rate will be maintained in 1981 despite the recession.

Estimates of the size of the installed base of automation equipment have been prepared by R. W. Hough and Associates Ltd. The estimates are shown in Table 1.

It is not clear from the source of Table 1 whether the projection for the number of word processors in 1981 represents stand alone systems or terminals on which word processing is carried out. Most observers foresee a strong market for stand alone systems until 1982 and 1983. After that, word processing will increasingly become a software product, where a central computer will serve a number of remote terminals.

The number of computers is expected to undergo the most rapid growth, from 18,000 units in 1978 to 150,000 units in 1985. Most of the growth will be accounted for by small computer systems. By 1985 the Canadian market for

mini and micro computers is expected to reach sales of $1.5 billion per year.

Overall growth in the Canadian terminal market averaged 32 per cent between 1976 and 1979. The colour graphics market is growing even more rapidly at 50 per cent to 60 per cent per year and could reach almost $1 billion by 1985.

The market for word processors is also expected to grow rapidly. There will be a shift away from stand alone systems to multi-terminal systems. In keeping with the trend of integrating word and data processing with telecommunications more and more of the word processors installed to 1985 will have communications capability.

The trends in the Canadian computer market are similar to those in the United States. In 1980 the total U.S. market for data processing and office equipment was $30.7 billion, a gain of 16 per cent over 1979. This compares to an estimated Canadian hardware market in 1980 of nearly $2 billion. In 1981 the market is expected to increase a further 17 per cent in dollar terms.

The small-computer segment of the market is expected to grow significantly faster than the total market. The segment includes small computer systems costing less than $100,000, word processing systems, desk top computers, and personal computers. It is expected to experience a compound growth rate of about 25 per cent per year over the next four or five years.

The market for display terminals, both "intelligent" and "dumb", is growing at a similar rate to the small computer segment. The market expanded about 23 per cent in 1980 and is expected to grow by 27 per cent to 28 per cent over the next few years. Graphics terminals are expected to do even better, increasing at a 35 per cent annual rate according to a prediction by International Data Corp. of Waltham, Mass.

Forecasts of the United States market for selected products are shown in Table 2.

The notable exceptions in terms of growth are medium and large computer systems where the market is expected to not quite double in size between 1980 and 1984. For the rest of the products listed in Table 2, the market is expected to be two to three times larger in 1984 than it was in 1980.

If the Canadian markets for word processors, small computers and terminals have not already reached the size that they can support a domestic industry, they will have grown to that point by 1985. A large domestic market, alone, is no guarantee of success for Canadian companies, but it does provide them with the opportunity to establish themselves in their own country before attempting to penetrate the much larger market south of the border.

Canada's Trade Position

Statistics Canada data for 1980 show net imports of $1.71 billion of computers and office equipment. Exports in 1980 were worth $739 million, resulting in a deficit of almost $1 billion. Despite some growth in the Canadian hardware industry the trade deficit has been increasing in recent years.

According to surveys conducted by Evans Research Corp. of Mississauga, Ontario, less than 9 per cent of the domestic computer hardware industry is Canadian owned. But with few exceptions the Canadian-owned companies are growing rapidly. While the 9 per cent figure for 1979 is low, it is a vast improvement over the 3 per cent figure for Canadian ownership in 1977.

Word processing equipment manufacturers have been Canada's hardware success story. Two Montreal-based companies, AES Data Ltd. and Micom Co. have made their mark in both domestic and export markets. AES Data Ltd. was formed in 1974. In 1978, Canada Development Corporation purchased a 64 per cent share of the Company. AES Data Ltd. is growing rapidly. Sales in 1980 were $160 million compared to $125 million in 1979 and $70 million in 1978. Some 2,000 people are employed worldwide by AES Data Ltd., the majority of which are based in Canada. AES products are marketed in over 50 countries. Export sales account for 60 per cent of total revenues.

Micom Co. is a subsidiary of Philips Electronics Ltd. of Toronto which is, in turn, owned by N. V. Philips of the Netherlands. Micom's 1980 sales were $100 million. It is second to AES Data Ltd. in terms of share of the Canadian market.

In 1979 imports of terminals and printers added $200 million to Canada's computer trade deficit. IBM Canada Ltd. is, by far, the largest terminal manufacturer in Canada. Its Toronto plant produces all of the company's 5251 display terminals for the world market. The next two largest (though much smaller than IBM) terminal manufacturers are Canadian owned. They are: Cybernex Ltd. of Ottawa and Volker-Craig Ltd. of Waterloo.

In the 1981 fiscal year Cybernex had sales of $6 million and employed 75 people. The majority of sales came from its line of video terminals. Most of the sales were in Canada, but the company is also active in the United States, Europe and Australia.

Volker-Craig designs, manufactures, and markets computer terminal products; mainly video display terminals. The company was established in 1973. By 1980 sales had reached $6 million and the company employed over 100 people in Canada, Europe and the United States. More than 75 per cent of production is exported.

Of the $2 billion computer hardware market, approximately half is for peripherals. The size of the market has made manufacturing of terminals in Canada attractive and there is a trend for companies that were established

as distributors to move into manufacturing. Lanpar Ltd. of Toronto, a major distributor of terminals in Canada, is reportedly moving into manufacturing of terminals under an import replacement program that is partly funded by the Federal government.

There are between 15 and 20 companies manufacturing computers in Ontario. Most of them have been established within the last few years and are Canadian owned. Though many of them are growing rapidly, their aggregate sales are too small to have much of an effect on reducing the computer hardware trade deficit. With the exception of Geac Computer Corporation Limited, which can be described as a specialized mainframe manufacturer, the Ontario-based computer companies produce mini and micro computers, primarily for the small business market.

Geac Computer Corporation Ltd. of Markham is the largest of the Canadian-owned computer manufacturers. It specializes in on-line systems for banking, prescription services and library circulation control. Sales in the latest fiscal year were $22.0 million. The company employs approximately 350 people in Canada, England and the United States.

Of the domestic manufacturers of small computers, Micos Computer Systems Inc. of Mississauga is the largest. It currently employs 44 people and expects sales to exceed $4 million in the current fiscal year. The majority of sales are in Canada.

## Opportunities for Ontario Manufacturers

Two of the most common themes that are heard when discussions turn to the Canadian microelectronics industry are that government support is woefully inadequate and that Canada is not short of technological capabilities to develop products. Where the weaknesses apparently occur is in manufacturing and marketing those products.

In the case of display word processors, it has been demonstrated that products could be developed, manufactured and marketed in Canada. The technology was developed by a small entrepreneurial company to take advantage of a market that began to develop in the early 1970s. But the two companies, AES Data Ltd. and Micom Co. did not become successful in terms of manufacturing and marketing until they were acquired by much larger companies; Canada Development Corporation and N. V. Philips respectively. Without the resources of the larger companies it is doubtful that AES and Micom would have reached their current position in the market.

It is difficult to speculate on the specific opportunities for manufacturers of office automation equipment since the Integrated Electronic Office is still a concept rather than a group of well defined products. However, there is a large and rapidly growing market for small business computer systems. Canada's position as a supplier of hardware to that market will depend, in large part, on how successful the 15 or so Ontario-based manufacturers of mini and micro computers are in making the transition from small companies to much larger companies. At the current stage their

strength is in technology and entrepreneurial drive. To grow they will have to acquire or develop strong financial, manufacturing, and marketing capabilities.

Small companies (including all but a handful of those in Ontario) purchase general purpose ICs and assemble them into a product. This allows them to quickly and cheaply develop products for specialized markets. However, the use of standard ICs restrict design options and performance. Should the product be successful it is vulnerable to being copied. Thus, for products aimed at large, highly competitive markets to be successful, they must contain the critical circuits on a proprietary chip. Custom circuits not only enhance the performance, reliability and cost of the product, but also make it very difficult and time consuming for competitors to copy the product.

It is extremely difficult for small companies to acquire a custom IC. Depending on the complexity, development costs can exceed $1 million. Small companies cannot afford the development costs and because they do not purchase large volumes, IC vendors will not take on the design of custom chips. Thus the situation arises where small companies cannot grow large without custom chips and they do not have the wherewithal to acquire custom chips until they are large companies!

In Canada, the larger companies such as Mitel and Northern Telecom have in-house capacity for custom chips. However, because there is such a small market for custom ICs in Canada there is a scarcity of chip designers and fabrication facilities. Those few Canadian companies active in the custom IC market, such as Siltronics of Kanata, ship the majority of their output to United States clients.

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Table 1

ESTIMATES OF THE NUMBER OF COMPUTERS, WORD PROCESSORS, AND TERMINALS IN CANADA

| ITEM | Number of Units 1978 | 1985 |
|---|---|---|
| Word Processors | | |
| Non-communicating | 18,000 | 65,000 |
| Communicating | 1,000 | 10,000 |
| Computers | 18,000 | 150,000 |
| Data Terminals | 250,000 | 700,000 |

Source: ( 4 )

Table 2

PROJECTIONS OF THE U.S MARKET FOR SELECTED OFFICE AUTOMATION PRODUCTS

| ITEM | Millions $ U.S. 1980 | 1984 |
|---|---|---|
| Computer systems, total | 14,030 | 25,881 |
| Desktop Computers | 945 | 3,000 |
| Small (less than $100,000) | 1,996 | 4,350 |
| Medium ($0.1 million to 1 million) | 3,746 | 6,025 |
| Large (greater than 1 million) | 7,343 | 12,506 |
| OEM Micros and Minis | 1,501 | 3,797 |
| Data Terminals | 2,226 | 5,507 |
| Graphics Terminals | 225 | 641 |
| Word Processing | 1,398 | 3,022 |

Source: ( 5 )

## COMMUNICATIONS AND COMPONENTS

### The Canadian Scene

The communications and components sector is the largest sector of the Canadian electronic industry. Its market represents about 46 per cent of the industry total.

Its products cover two main groups, electronic equipment and components.

The equipment includes all types of electronic communication devices such as:-

- Radio and TV transmitters
- Control devices
- Closed circuit television
- Alarm and signal systems
- Electronic navigational aids
- Sound systems
- Telephone equipment
- Telegraph equipment
- Repair and overhaul of above.

The components are used to manufacture this equipment plus other electronic products, e.g., radio, TV, toys, computers, controls. Components include:

- Semiconductors
- Capacitors
- Printed circuit boards
- Quartz crystals
- Television picture tubes
- Transformers
- Connectors

The companies manufacturing the commodities in this sector are as diverse as the products themselves with 334 establishments across Canada in 1978.

More than half of the Canadian establishments - 56 per cent - are located in Ontario and account for 63 per cent of Canadian factory shipments. 75 per cent of the establishments in Ontario had less than 100 employees. Of the total Canadian shipments 10 per cent of the companies shipped 82 per cent of the goods.

Not only is this the largest sector within the industry but it also has the best trade performance. Strong exports and a lower than industry average import penetration - 53 per cent vs 66 per cent - gives it the lowest percentage trade deficit of the group - 23.6 per cent of Apparent Domestic Market against an industry average of 36.3 per cent.(1)

Exports from the communication equipment sector alone exceeded imports by 34 per cent in 1979 and only the massive imports of components resulted in an overall negative trade balance. The potential for growth for communications equipment is tremendous. The demand for an ever increasing volume of intelligence of all sorts - the Information Society - is bringing with it a revolution to which the Microelectronic Revolution is itself inextricably linked.

Because the demand for information is world wide - not a purely Canadian phenomenon - Canada's past performance in this sector is no guarantee of future success. It is to be anticipated that aggressive competition from foreign suppliers will increase further and domestic and export markets will be hotly contested. Intelligent industry action and government policies will be needed to maintain Canadian domestic market share and to continue the export thrust.

One of the key ingredients to such success will be product innovation. The Canadian electronic industry is the largest single spender on R & D running about 4.5 times the national average. However, with the huge sales volumes of the world leaders our expenditures on R & D in absolute dollars look miniscule.

The growth in the equipment sector could provide an equal opportunity to the components group. However, the components industry is going through a major period of adjustment. We have already seen that the switch from domestic manufacturing to importation for household radio and television dealt component manufacture a serious blow.

The current trend away from discrete components to integrated circuits, which is implicit to the whole field of microelectronic development, is causing further change.

To satisfy the huge demands for standardized components for world markets requires plants capable of producing at world scale levels. Most Canadian components manufacturers do not have such facilities but they could be established, in the same way as component plants have been set up in other jurisdictions. It is most probable, however, that growth will come from the

supply of special purpose components whose volume and facilities are more closely in line with existing Canadian capabilities.

Canadian component manufacturers have demonstrated an ability to specialize and succeed in many areas, such as printed circuit boards, quartz crystals, connectors, transformers, colour picture tubes, selected semiconductors and integrated circuits.

In 1980, we exported a diverse array of component types worth about $310 million. However, in the same year we had a trade deficit in components of about $890 million since we imported more than $1200 million of miscellaneous components. Of this, over $490 million were for semiconductors and integrated circuits.(2)

No matter what caveats may be used to interpret Canadian semiconductor statistics it is clear that, based on consumption of approximately $400 million, only in the order of 10 per cent were produced in Canada. Furthermore, most of those went from captive suppliers to their asssociated equipment manufacturing facilities.

This raises a key question as to whether active participation in total microelectronics manufacture necessitates active participation in the manufacture of semiconductors. A corollary, if the primary question is answered affirmatively, is whether such semiconductor manufacture should involve a wide range of standard components or whether specialized manufacture of custom chips would suffice. In that several manufacturers have elected to follow the latter route, albeit only for their own needs, some conclusions have already been reached.

There are staunch advocates of the need to establish Canadian chip manufacturing facilities capable of producing standard chips and custom derivatives. This advocacy is made mainly on the basis of security of supply. Others contend that the cost of establishing such a facility is too prohibitive to justify the supply benefits, that no one facility could provide the full range of standard products made by all suppliers, and that, although there have been temporary shortages in supply, there is no long range supply problem.

## Canada and Ontario in the International Perspective

The past 10 years has witnessed a universal demand for more and better communications and the information that it can provide. More and more the economy is characterized as much by information-related activities as it is to transactions in goods and services. Already new technological developments have responded to this demand.

Man's conquest of space has permitted the development of communications satellites whose stationary orbit provides high quality worldwide communications for a wide spectrum of services including telephone, television, data and general telecommunications.

There are other significant developments. The substitution of digital signal processing for the analog system has revolutionized communications methods. It also has the sophistication and maturity of software control. Behind these two developments lie the ever-pervasive microelectronic technology which has made all other technological developments possible.

The marriage of computer technology with the developments in communications has produced new services unavailable with previous techniques and has blurred the lines of distinction between these two information processing groups.

The Canadian Radio-Television and Telecommunications Commission (CRTC) has accelerated the blending of interests by relaxing the barriers to interconnection to information networks. These decisions have brought a new competitiveness to the Canadian communications industry and broadened its markets.

The ability of Canadian manufacturers to meet the technological requirements of this communications era has been supported by a new awareness of, and demand for, products exhibiting technological sovereignty. More and more, Canadian governments and private businesses are insisting on products developed and manufactured in Canada.

The unquestioned leader in this case has been Northern Telecom Limited whose 33,000 employees world wide and 1980 total sales of over $2 billion rank it the largest company in the communications sector and indeed the entire electronics industry. By its own estimate it supplies 70 per cent of the Canadian market for telecommunications equipment.

Until 1956, Northern Telecom (then Northern Electric) operated as a subsidiary of U.S. Western Electric and was wholly dependent on that company for technology. As a result of a U.S. Justice decree in that year, defining the relationship of Bell U.S. and Western Electric, the transfer of such technology on its previous terms was precluded. Bell Canada acquired majority control of Northern and this chain of events represented the major turning point in the company's history.

Forced to develop its technology in Canada, Northern began to provide massive support for Canadian R & D. Through Bell Northern Research it is the largest single R & D spender in Canada, contributing approximately 7 per cent of its sales dollars. This is many times the national average for all manufacturing, now below 1 per cent, and more than 4 times the national objective of 1.5 per cent.

The dividends of this investment are reflected in the company's growth. In 1972 annual sales were $531 million, by 1980 nearly 4 times that amount. Northern operates 55 plants in Canada, United States, England, Eire, Turkey, Malaysia and Brazil. It is the only Canadian manufacturer which produces the complete telecommunication product range including switching, transmission and outside plant equipment and all types of subscriber

apparatus. In the 1972-1978 period profits rose five fold from $20 to $100 million on a three fold growth in sales.

The key component to telephone and other telecommunication systems is central office switching equipment. Ever since the first automatic switching systems were introduced this equipment had been electro-mechanical with its attendant failure and maintenance problems. Northern decided that it would develop an all-electronic switch, and in 1971, after development costs of $90 million, it introduced the SP-1 electronic analog switch.

The acceptance of this product resulted in sales of $900 million in Canada, the U.S. and other foreign markets over the next six years and a recovery of the R & D costs. More significantly, it announced to the world at large that Canada, through Northern, was a world leader in telecommunications technology.

Although the potential sales for the SP-1 was far from realized, Northern capitalized on its earlier success by introducing a new generation of digital switching equipment in 1977. The management of the company believed that digital switching would attract a wide and rapid following and that the first company to offer such a product would command an advantage over its world competition. The so-called DMS equipment went into service in 1977 as a 256-line switch, the DMS-1. Larger versions of the equipment with as high as 100,000 lines followed and again the product had widespread acceptance in Canadian and foreign markets. In March, 1979 Northern had 800 systems in service or on order. One year later the number was nearly doubled to 1506.

A second major Canadian telecommunications supplier is AEL Microtel Ltd. It was formed in 1979 by a merger of two U.S. General Telephone and Electronics subsidiaries - Automatic Electric of Brockville, Ontario, and Lenkurt Electric of Burnaby B.C. The combined company was formed when it was acquired by B.C. Telephone, itself a subsidiary of GTE and the major customer of Automatic and Lenkurt.

Their 1978 sales totalled about $150 million, with $103 million ascribed to Automatic and $48 million to Lenkurt. Most of Automatic sales were to B.C. Telephone and other GTE subsidiaries. However, the trend from electro-mechanical to electronic switches had a major impact on both sales and profitability and necessitated major capital expenditure to convert the Brockville plant to electronic production.

AEL Microtel has combined its R & D operations under Microtel Pacific Research Ltd., although the two divisions will continue to conduct their own development work on manufacturing processes and equipment. The rationalized R & D will reduce duplication and permit an integrated approach to the company's consolidated needs. This new facility presently employs 230 staff and will have spent $16 million on R & D by 1984.

AEL Microtel is expecting to recapture some of its lost sales with the development of new products matched to market needs. It is anticipated that by 1984 sales will reach $250 million. Some of that increase will come from a new line of business: video display terminals based on Telidon technology and aimed at the 'office of the future'.

AEL Microtel and Northern Telecom each have a special relationship with the telecommunications carriers. However, there are a number of other Canadian communication equipment manufacturers without such linkage but who represent a major segment of this industry group. Their sales range from $10 to $100 million and their products are diverse. They include 14 manufacturers whose total sales volume of $600 million is 1/3 the sales of Northern Telecom, or 4 times that of AEL Microtel.

The earliest electrical/electronic communications systems utilized wire and cable. Other communications systems include mobile radio, microwave, satellite and data. Some of the companies involved in this sector, and their products, are:

| Company | Product |
|---|---|
| Canada Wire and Cable Co. | Wire and Cable |
| Phillips Cables | Wire and Cable |
| Pirelli Cables | Wire and Cable |
| Motorola Canada | Mobile radio |
| CGE | Mobile radio |
| Canadian Marconi | Microwave, avionics |
| Raytheon | Microwave radar |
| Rockwell Collins | Microwave, telecommunications |
| Farinon Canada | Microwave |
| Spar Aeorspace | Satellite, aerospace |
| Gandalf | Digital communications |
| Mitel | Telecommunications and integrated circuits |
| Leigh Instruments | Industrial electronics |
| SED Systems | Aerospace, satellite and general telecommunication and control. |

A detailed discussion of each of the firms is provided in a recently published report of the Federal Department of Communications entitled 'The Supply of Communication Equipment in Canada',(3).

Despite the diversity in products, company sizes and markets, one factor clearly emerges. The successful companies are those who have selected a specific product and market niche and developed their basic corporate strategy around them.

Part of this corporate strategy involves adequate R & D funding for the selected products. This funding is usually in the range of 3-5 per cent of annual sales.

A more detailed examination of two of the most successful companies suggests an even closer linkage between successful growth, product specialization and R & D.

The two companies are Gandalf and Mitel. They exhibit a marked similarity. They are both located in the Ottawa region. Gandalf was started in 1970, Mitel in 1971. Both are Canadian owned.

Both have had impressive sales records. Gandalf sales have grown 50 per cent per year since its inception. Mitel sales have at least doubled each year since 1974. Gandalf sales were \$13 million in 1979 and \$26 million in 1980. Mitel sales were about \$22 million in 1979, \$43 million in 1980 and over \$110 million in 1981.

Both companies are strong supporters of R & D at expenditure levels about 10 per cent of annual sales. Both companies export heavily. Gandalf exports approximately 50 per cent of its production, Mitel about 79 per cent.

Gandalf's products are supplied to the computer industry and include modems- devices to couple computers to telecommunication links - and automatic exchanges for computers.

Mitel have concentrated their production on private branch exchanges for telecommunications. Recognizing the need for microelectronic circuitry they have a vertically integrated facility to supply their own requirements for large scale integrated (LSI) chips. Located in Bromont, Quebec, this facility is the second largest in Canada and is scheduled for expansion. Although established to satisfy their own design and production requirements, the components of this plant have also been made available to other electronic manufacturers. In 1979, two-thirds of the total production went to outside customers.

Considering the dramatic growth of these two companies, the performance of smaller companies - those with annual sales of under $10 million - could indicate the next group of growth companies. Most of these companies are manufacturers of components, some produce finished systems or products. There are 64 such firms across Canada with 45 of them in Ontario, 11 in British Columbia and the balance of 8 in Quebec and the Atlantic Provinces.

They show a very similar ratio of exports to total sales - about 34 per cent - regardless of total sales volume as indicated in Table 1.

The international nature of telecommunications has produced an international environment in which the equipment manufacturers operate.

Northern Telecom, whose sales of $2 billion make it by far the largest electronics company in Canada, appears far smaller when viewed in the world context. Table 2 lists the 13 major telecommunication manufacturers and Northern ranks 13th on this list. However, this comparison is related to total sales of all products, and is not limited to telecommunications equipment. International Telephone and Telegraph, who with $19.4 billion sales (U.S.) heads the list, is a multiproduct company whose interests range across a wide industrial base as well as hotels, insurance and finance. Viewed only in comparison to the telecommunications component of company sales, it has been estimated that Northern would rank in the first half-dozen companies.

The combined 1978 sales of all companies listed totals over $100 billion. All indications are that sales for 1980 would be considerably higher, yet total world sales of communications equipment for 1980 were estimated at U.S. $40 billion. This would suggest that only about 1/3 of all sales shown are in such equipment although this would vary significantly on a company by company basis.

Many of these international companies have established a presence in Canada. This may simply involve a subsidiary which imports products for the Canadian market, a facility capable of assembling or testing imported system components or full manufacturing. Table 3 shows their telecommunications operations as related to overall Canadian sales.

The international companies who rely on imported products seem to be less successful than those who manufacture here. This is a reflection of the demand for technological sovereignty by many Canadian buyers and the response of Canadian manufacturers to satisfy that demand against which imported products, particularly those with European designs, find less acceptance.

In world markets, all of the major companies are strong contenders. In specialized markets many smaller companies have found their particular market niche. This fact is supported by the high level of exports from Canadian communications equipment manufacturers despite the fact that only one of these is a member of the '$1 Billion Club'.

The total world market for telecommunications equipment is estimated at $40 billion U.S. for 1980 according to a recent study by Arthur D. Little.(3) The study estimates an annual growth rate of 8-1/2 per cent and total sales of $87 billion by 1990.

Although North America is, and will remain, the largest market, its maturity will not make it the fastest growing. The Far East and Middle Eastern markets have much less sophisticated communications systems and the buoyancy of these economies will support modernization and extension of these services.

It might seem that in a market of $40 billion there would be room for many manufacturers to operate in an environment of little competition. It is doubtful, however, that this condition would prevail in any size market due to the highly aggressive selling tactics of the major players. Backed by vast corporate resources, which at the same time demand continuing orders to justify their existence, the major manufacturers establish the business environment in which all competitors must operate.

Moreover, all of the $40 billion potential is not readily available. In developed countries government procurement policy usually reflects either a preference for domestically produced goods for which premiums may be paid, or may actually preclude other than domestic suppliers from tendering. Major telecommunications carriers may also have a direct corporate linkage with their suppliers who thus have a favoured position denied to outside and foreign suppliers.

In such markets often the only means of access is a licensing agreement or joint venture with a domestic supplier who can participate.

The developing countries are in comparison usually much more accessible. There may be some slanting of the market by tied-aid programs, or past procurement practice, but these usually present a far less prohibitive barrier than that exhibited by developed countries.

Because of these prevailing protectionist policies it is estimated that 80 per cent of the $40 billion is not accessible to Canadian manufacturers.

Only about 20 per cent, or $8 billion, is open to competitive bidding and that volume is hotly pursued by telecommunications manufacturers world wide.

The North American market does not exhibit the same degree of protectionism experienced elsewhere. Although some domestic preference is a matter of U.S. procurement policy it rarely extends to an outright refusal to deal with foreign suppliers and in such an environment Canadian manufacturers have had a high degree of success. In some cases, however, to get full access to the market it has been necessary to establish U.S. manufacturing facilities.

One could assume that at least the total Canadian market was readily accessible to all Canadian manufacturers. Indeed, considering the relatively small size of the market and the needs for extensive communication systems to cope with vast distances, it would not be surprising if Canadian government policy was highly protective of its suppliers.

These assumptions are not supported by the facts. Governments in many provinces are also operators of the provincial telephone systems. By procurement policy they have shown preference to local plants and companies resulting in unnecessary fragmentation of Canadian manufacturing. Since only the major manufacturers can afford the luxury of responding to such pressure, smaller manufacturers find that access to the whole market does not exist from a one-plant facility.

In North America, there has been an increasing federal government concern about the linkage between carriers and subsidiary suppliers, e.g., AT & T and Western Electric, Bell Canada and Northern Telecom and B.C. Telephone and GTE/AEL-Microtel. In Canada an investigation has gone on for several years and has accumulated many thousands of pages of testimony. One of the outcomes of this investigation has been to change the policy of interconnection with carriers' communications networks.

This has meant that, providing the equipment is in accordance with network standards, it need not be supplied by the carrier himself. Suddenly a whole new market for equipment compatible with the carrier's system can be sold directly to the consumer, whether industrial, commercial or residential.

A similar but earlier ruling in the United States has already opened that market to other than the subsidiary suppliers of the telecommunications companies. Canadian companies have already benefited from this market relaxation, and in some cases by the establishment of facilities in the United States.

European and Japanese products had not previously made much market penetration. The controlled access to the total market had resulted in an extremely small available volume and little economic justification for redesigning offshore designs to suit the North American market. However, the relaxed interconnection policy permitted such companies to establish manufacturing subsidiaries in the United States from which they now compete with both American and Canadian manufacturers.

Since Canadians in the United States market are also 'foreign' manufacturers, the establishment of such operations is no different than Canadian actions. However, since these companies now also have ready access to the Canadian market, they constitute a new source of competition in the Canadian domestic market.

The accessibility to the United States markets is reflected by Table 4 which lists our principal trading partners. It is significant in light of the previous comments on market access that 11 per cent of our total imports come from Japan and yet exports of communications equipment to Japan are too small to have statistical significance.

Canada can continue to exhibit world class competence in telecommunications but such leadership is neither automatic nor assured. It has resulted from a blend of Canadian ingenuity and entrepreneurship supported by competent management, aggressive marketing and massive R & D support.

References:

(1) Electrical and Electronic Industry, Abstract of Industry and Trade Statistics, ITC, 1979.

(2) Electrical and Electronics Industries, Statistical Summary, ITC, 1980.

(3) The Supply of Communications Equipment in Canada, Department of Communications, OTTAWA, 1981.

Table 1

SALES, EXPORTS, IMPORTS AND EMPLOYMENT OF SELECTED SMALLER FIRMS BY SIZE CATEGORY (1978)

| NO. OF FIRMS | | SALES ($ MILLION) | EXPORTS (AS % SALES) | IMPORTS (AS % SALES) | EMPLOYMENT |
|---|---|---|---|---|---|
| SALES: $2 MILLION | | | | | |
| 37 | Total | 33.1 | | | 1533 |
| | Average | 0.9 | 32.1 | 22.7 | 41 |
| SALES: $2 — $5 MILLION | | | | | |
| 16 | Total | 51.1 | | | 2308 |
| | Average | 3.2 | 34.0 | 21.3 | 144 |
| SALES: $5 — $10 MILLION | | | | | |
| 11 | Total | 80.1 | | | 1625 |
| | Average | 7.3 | 35.3 | 5.9 | 148 |
| CANADIAN TOTAL | | | | | |
| 64 | Total | 164.3 | | | 5466 |
| | Average | 2.6 | 33.6 | 19.7 | 85 |

Source: ( 3 )

Table 2

WORLD COMMUNICATIONS EQUIPMENT MANUFACTURERS WITH 1978 SALES* OF COMMUNICATIONS EQUIPMENT EXCEEDING $1 BILLION

| MANUFACTURER (IN ORDER OF TOTAL SALES) | TOTAL SALES ($ BILLION) | | COMMUNICATIONS EQUIPMENT SALES ($ BILLION) | | TOTAL NUMBER OF EMPLOYEES | BASE COUNTRY |
|---|---|---|---|---|---|---|
| 1. International Telephone & Telegraph | US | 19.4 | US | 4.7 | 379,000 | US |
| 2. Philips Lamp Holding Company | C | 17.3 | C | 4.4 | 387,900 | Holland |
| 3. Siemens AG | C | 16.5 | C | 3.1 | 322,000 | FRG |
| 4. Hitachi* | US | 10.8 | US | 1.8 | 138,700 | Japan |
| 5. Western Electric | US | 9.5 | US | 9.5 | 161,000 | US |
| 6. General Telephone & Electronics | US | 8.7 | US | 1.8 | 214,000 | US |
| 7. Rockwell International | US | 5.7 | US | 1.3 | 114,200 | US |
| 8. General Electric Company (UK) | C | 5.5 | C | 2.1(E) | 178,600 | UK |
| 9. Cie Générale d'Électricité | C | 5.2 | C | 1.4 | 104,900 | France |
| 10. Thomson-Brandt* | C | 4.3 | C | 2.2 | 109,200 | France |
| 11. Nippon Electric Company | US | 3.7 | US | 1.4 | 60,500 | Japan |
| 12. L.M. Ericsson | US | 2.1 | US | 2.1 | 61,400 | Sweden |
| 13. Northern Telecom | C | 1.5 | C | 1.5 | 31,400 | Canada |

*1977 data for Hitachi and Thomson-Brandt; 1978 data for all other companies

(E) Estimates. General Electric (UK) does not report net product group sales or intra-company sales.

The Canadian and U.S. company sales are quoted in the dollar currency reported. The sales of overseas companies are converted to Canadian dollars at the average exchange rate for 1977 or 1978, except for Nippon, Hitachi and Ericsson which report in US dollars.

Source: ( 3 )

Table 3

TELECOMMUNICATIONS OPERATIONS
SELECTED FOREIGN SUBSIDIARIES

| COMPANY NAME | TOTAL SALES | CANADIAN TELECOM SALES | TOTAL EMPLOY. | TYPE OF OPERATION |
|---|---|---|---|---|
| AEI Telecommunications | 9 (79) | 9 | 130 | Limited Assembly & Test. |
| L.M. Ericsson Ltd. | 19 (77) | 9 | N/A | Distributor |
| ITT Canada Ltd. | 540 (78) | 25 | 500 | Manufacturer |
| Philips | 150 (78) | N/A | 2200 | • Manufacturer Consumer Products including 'MICOM' word processors<br>• Distributor only for Telecom products |
| Plantronics Canada | 2 (79) | 2 | 25 — 30 | Limited Assembly and Tests |
| Plessey Canada | 9 (78) | 8 | 200 | Manufacturer |
| Pye | 6 (79) | 6 | 80 | Systems Design and Modifications to imported Equipment |
| Siemens | 80 (79) | 30 | 400 | Manufacturer |

ALL SALES IN CANADIAN $ MILLION

Source: ( 3 )

Table 4

PRINCIPAL TRADING PARTNERS
COMMUNICATIONS AND COMPONENTS

| CANADIAN EXPORTS TO | 1979 |
|---|---|
| UNITED STATES | 63% |
| UNITED KINGDOM | 4% |
| TURKEY | 3% |
| IRELAND | 2% |
| SWEDEN | 1% |
| **CANADIAN IMPORTS FROM** | |
| UNITED STATES | 75% |
| JAPAN | 11% |
| UNITED KINGDOM | 4% |
| TAIWAN | 1% |

Source: ( 2 )

## INSTRUMENTS AND CONTROLS

### The Canadian Scene

The demand for centralized processing and control of data that has caused the computer to dominate the office function has had a parallel in manufacturing. Instrumentation and control devices to monitor and operate manufacturing processes have become an integral part of manufacturing facilities.

The heavy orientation to resource industries in the Canadian economy has given a major stimulus to this electronic equipment sector. Mining, petrochemical plants, steel mills and pulp and paper mills are amongst the larger consumers. Not only do the manufacturing processes themselves and the need for increased productivity provide the demand so also does equipment for energy conservation and environmental monitoring and control. This has led to the Canadian market doubling every 7 years since 1965 and this trend is expected to continue and increase.

Because most instruments and control devices are integrated into computing and communications systems there is a considerable overlap with these sectors and this results in some imprecision with sector statistics.

Some of the typical products are:

- Electronic test and measuring equipment
- Aircraft and marine navigational instruments and systems
- Temperature measuring, indicating and control equipment
- Geographical instruments and apparatus
- Equipment measuring and controlling pressure, flow, heating and cooling, motion, rotation, and time
- Medical instruments and apparatus
- Photographic equipment.

The Federal Department of Industry, Trade and Commerce has recently published a sector profile (1) of the industry based on data from a company survey carried out in 1979.

This profile identifies 7 separate subsectors which are highly differentiated from one another by product, type of technology, methods of distribution, markets, industry and company size, and level of foreign ownership. The seven subsectors are as follows:

1. Industrial Process Control, Instrumentation and Automation Equipment and Systems;

2. Building Instrumentation and Automation Equipment and Systems;

3. Biomedical and Health Care Instrumentation;

4. Electrical, Electronic Data and Logic Test and Measurement Instruments and Systems;

5. Scientific, Analytical and Laboratory Instrumentation;

6. Remote Sensing and Environmental Instrumentation; and

7. Geological, Geophysical and Geotechnical Apparatus

Statistics Canada listed 183 establishments throughout Canada manufacturing instrumentation equipment in 1978. Most of these - 68 per cent - are in Ontario and 85 per cent of the total output comes from this province.

The sector exhibits the pattern typical of the electronics industry in Canada - a small number of large subsidiaries of foreign multinational companies and a large number of small Canadian-owned companies. The former produce product lines typical of their parent facility. The latter produce highly specialized products for custom applications and reflect the business experience and expertise of their entrepreneurial owners.

Eight per cent of the total companies produce 75.1 per cent of the shipments. Three establishments have over 500 employees, most have under 20. Eighty percent of the firms in this sector in Canada have annual sales of under $2.5 million. Even the largest companies are relatively small by international standards. Of nine companies reporting annual sales in excess of $10 million, only three exceed $30 million.

The 1978 domestic market was just under $1 billion.(2) Exports reached $98 million. Canadian production accounted for $581 million of this combined market. Imports of $473 million supplied the balance and contributed to a trade deficit of $375 million. The United States represented both the major export customer and supplier, Tables 1 and 2.

The North-South relationship is of course typical of most Canadian trade. However, the export markets outside the United States also show a degree of acceptance of Canadian products in highly industrialized markets.

The major Canadian manufacturers include such companies as Edwards Company of Canada, Foxboro Company of Canada, Honeywell Limited and Johnson Controls. All of these are capable of taking instrumentation and control systems from concept through design and installation on a turn-key basis. This can include software development, hardware production or procurement, operational training of customer personnel, and installation, service and maintenance.

The smaller companies in the sector produce a highly selective range of products in each of the 7 subsectors and may be suppliers of hardware components for major systems. Many of them are relatively new, having been in existence for under 10 years. The Canadian-owned firms are heavily export oriented and, in 1978, 35 per cent of their output went to foreign markets as compared to an industry sector average of about 20 per cent (Table 4).

The market life of many products in this sector is shortened by rapid advances in technology. The use of microelectronics is a major factor in incorporating the cost and performance improvements imperative to product development. In order to maintain world competence, a high degree of R & D is necessary. That the industry responds to this need is supported by the following table indicating that 10 per cent of the total employees in the sector were engaged in R & D activities Table 3.

## Canada and Ontario in the International Perspective

In the major foreign-owned companies their performance in Canada is mainly dictated by corporate agreement. Whether the Canadian subsidiary serves any, all or specific export markets, or is a world specialist in manufacturing particular products, is by negotiation with the foreign parent. Canadian government influence will be chiefly limited to being seen to provide an hospitable regulatory and business environment.

The Canadian-owned company does not operate under such conditions which, for his foreign-owned counterpart, may be both restrictive and protective. He gets little protection in his own domestic market. He gets none in the export field - a market we have seen is 35 per cent of his total. Due to a high degree of product specialization, the domestic market is too small to satisfy his production capacity and the export market is, therefore, a mandatory alternative.

For the smaller company, the cost of export marketing and servicing the foreign account represents significant drains on the company's usuually limited financial resources. These have already been strained to provide funds necessary to continue the R & D required to maintain a competitive product advantage.

The DITC sector profile found that the shortage of skilled personnel was also an inhibiting factor to growth. Systems designers, software engineers and technicians necessary to install, maintain and service the equipment are in increasingly short supply. The shortage is also inhibiting to some degree the application of new technologies by the potential users who lack the necessary expertise to operate sophisticated instrumentation and control systems.

The shortage of personnel, although widespread, is a greater problem for the small company. The large company can afford to carry out extensive training to at least partially satisfy its need for skilled personnel. Furthermore, its pay levels, fringe benefits, and presumed stability, may provide a

greater appeal to the recent graduate. The smaller company usually lacks the necessary staff to develop in-house training and may have difficulty matching the compensation levels of his major competitors. However, for some technical staff, the freedom associated with small company operations has a greater appeal.

Although the Canadian companies operate successfully in the international environment, foreign manufacturers also are equally successful in the Canadian domestic market. The following table indicates that, in some of the subsectors, only 10 per cent of the domestic market is served by local suppliers. Yet in these same categories export levels of 50 per cent are quite common. This, of course, is due to the product specialization (Table 4).

The variations in product classifications from one source to another make estimates of foreign markets difficult to assess. DITC has used data from its own sources, from the U.S. magazine Electronics, from the U.S. Electronic Industries Association publication Electronic Data Book 1978, and The Mackintosh Yearbook of the Western European Electronics Data 1980, to arrive at a composite market estimate of just under $20 billion, as shown in Table 5.

These statistics have been compared with a 1976 Stanford Research Institute study of the North American market and would seem to provide reasonable correlation when the latter is projected to 1978. The SRI study provides an interesting breakdown of the comparative sizes of the various subsectors (Table 6).

The Canadian market will continue to be dominated by the major manufacturers although Canadian specialists will still obtain product acceptance in specific markets.

Demand will continue to be affected by the ability, of users to adopt new technology, e.g., technical ability to operate and maintain equipment, attitude, capital commitments to current manufacturing processes.

Skilled labour shortage, both for supplier and user, will continue to inhibit both supply and utilization of new equipment.

Export marketing provides considerable strain particularly on smaller companies' resources as does the limited capability to service foreign installations. Small companies also experience difficulty in major turn-key projects except as a supplier to others. Foreign suppliers operate in world markets with various levels of home government support and represent formidable competition to Canadian companies lacking such concrete assistance.

The future for the industry can be good but there are a number of problems to be addressed if its full growth potential is to be realized.

## References

(1) Instrumentation and Industrial Process Control Systems - Sector Profile, ITC, 1981.

(2) Electrical and Electronic Industry, Abstract of Industry and Trade Statistics, ITC, 1979.

Table 1

## PRINCIPAL TRADING PARTNERS — INSTRUMENTATION —

| CANADIAN EXPORTS TO | 1979 |
|---|---|
| UNITED STATES | 63% |
| WEST GERMANY | 6% |
| UNITED KINGDOM | 4% |
| AUSTRALIA | 2% |
| MEXICO | 2% |
| **CANADIAN IMPORTS FROM** | |
| UNITED STATES | 83% |
| JAPAN | 7% |
| UNITED KINGDOM | 3% |

Source: ( 1 )

Table 2

## INDUSTRY SIZE AND STRUCTURE, 1978

| SUBSECTORS | DOMESTIC MARKET ($ M) | TOTAL REPORTED SALES ($ M) (2) | NUMBER OF COMPANIES | TOTAL EMPLOYMENT |
|---|---|---|---|---|
| Industrial Process Control Systems & Instrumentation | 325 | 263 | 135 | 5300 |
| Building Instrumentation | 271 | 203 | 36 | 4960 |
| Medical Electronics | 164 | 55 | 20 | 1300 |
| Test & Measurement Instruments | 85*(1) | 16 | 30 | 600 |
| Scientific & Laboratory Instrumentation | 60*(1) | 12 | 13 | 400 |
| Remote Sensing & Environmental Instrumentation | 32 | 20 | 30 | 600 |
| Geophysical Apparatus | 25*(1) | 11 | 21 | 365 |
| SECTOR TOTAL | 962 | 580 | 285 | 13525 |

Note: (1) The figures which have been marked with an asterisk are considered to be low estimates of the size of the domestic market.

(2) Sales can include goods imported from parent company and do not necessarily represent Canadian manufactured shipments.

Source: ( 1 )

Table 3

## R & D ACTIVITIES — INSTRUMENTATION SECTOR

| SUBSECTORS | TOTAL R & D EMPLOYMENT | R & D EMP. AS % OF TOTAL EMP. | SALES REV. PER UNIT OF R & D EMP. |
|---|---|---|---|
| Industrial Process Control Systems & Instrumentation | 585 | 11% | $ 450,000 |
| Building Instrumentation | 65 | 1% | 3,123,000 |
| Medical Electronics | 120 | 9% | 458,000 |
| Test & Measurement Instruments | 110 | 18% | 145,000 |
| Scientific & Laboratory Instrumentation | 130 | 32% | 92,300 |
| Remote Sensing & Environmental Instrumentation | 170 | 28% | 117,600 |
| Geophysical Apparatus | 125 | 34% | 88,000 |
| SECTOR TOTAL | 1305 | 10% | $ 444,000 |

Source: ( 1 )

Table 4

## CANADIAN INSTRUMENTATION INDUSTRY PERFORMANCE IN DOMESTIC AND EXPORT MARKETS

| SUBSECTORS | TOTAL REPORTED SALES ($ MILLIONS) | EXPORTS AS % OF SALES | % OF DM FROM DOMESTIC SOURCES |
|---|---|---|---|
| Industrial Process Control Systems Instrumentation | 263 | 17% | 66% |
| Building Instrumentation | 203 | 7% | 70% |
| Medical Electronics | 55 | 58% | 18% |
| Test & Measurement Instruments | 16 | 45% | 10% |
| Scientific & Laboratory Instrumentation | 12 | 49% | 10% |
| Remote Sensing & Environmental Instrumentation | 20 | 46% | 33% |
| Geophysical Apparatus | 11 | 55% | 19% |
| SECTOR TOTAL | 580 | 20% | 48% |

Source: ( 1 )

Table 5

## INSTRUMENTATION AND PROCESS CONTROL EQUIPMENT WORLD MARKETS — 1978

| | DOMESTIC MARKETS (IN $ MILLIONS) 1978 | ANNUAL GROWTH RATE |
|---|---|---|
| U.S. | 9500 | 14% |
| Japan | 2500 | 14% |
| Western Europe* | 6500 | 15% |
| E.E.C. | 5400 | 15% |
| Canada | 970 | N/A |
| TOTAL | 19500 | |

* (E.E.C. plus Sweden, Norway, Spain, Switzerland, Austria, Finland.)

Source: ( 1 )

Table 6

## ESTIMATED MARKET — NORTH AMERICA

| | 1976 $ MILLIONS | REAL ANNUAL GROWTH RATE 1976 — 80 |
|---|---|---|
| Process Control | 1,600 | 4.0% |
| Laboratory Instrument | 500 | 3.0% |
| Biomedical | 2,750 | 5.5% |
| Industrial (Test and Automation) | 400 | 10.0 to 20% |
| Electrical Test and Measurement | 1,300 | 5.0% |
| Electro-Optical Non Defence | 1,000 | 13.0% |
| Residential and Construction | 1,000 | 3.5% |
| Energy, Resource, Exploration and Environment | 350 | 12.0% |
| TOTAL | 8,900 | |

Source; ( 1 )

## AUTOMATED MANUFACTURING

There remain few technological barriers to the advent of the automatic factory. The concept of the automatic factory, taken to its ultimate, would involve all operations - from handling of raw materials when they arrive at the factory gate through to packaging of the final products - being performed without human operators. The only human involvement would be to control and monitor the operations and to maintain the equipment. Economic factors, rather than technological limitations, are behind the slow emergence of the automatic factory.

Cost effectiveness and availability of capital are the two criteria most commonly used to assess the feasibility of introducing new technology. Even if it can be shown that an automatic factory is the most cost-effective solution, the huge amount of capital required to build such facilities will slow their introduction. While the fully automated factory is still, realistically, decades away, in the near term we can expect increased levels of automation in existing factories. Automated systems to handle functions such as material handling, fabrication of parts, assembly, quality control, and virtually all of the other activities involved in manufacturing are finding their way into the factory. At the heart of these systems (and, indeed, the development that made most of them possible) is the computer.

The main driving force behind the move to more automation in manufacturing plants is the imperative to remain competitive with the leading industrial nations. The economics of scale inherent in most manufacturing processes, the lowering of tariffs and non-tariff barriers and other factors, have dictated the need for manufacturers to compete in world markets. To do so requires productivity that matches that of competitors when differences such as costs and transportation fees are taken into account. Growth in productivity of North American industry has been slower than in most other industrialized countries and, as a result, the industry has become less able to compete in world markets. An essential element in improving productivity is greater investment in technology and modern plants. For any industrialized country that wishes to remain so, while improving or at least maintaining its standard of living, there are few options to automating its factories.

Until the advent of cheap, reliable, programmable electronics, automation was only feasible in mass production environments. In order to justify the costs of specialized tooling and equipment (often referred to as 'hard automation'), long production runs, little variability amongst products, and few changes in raw materials are necessary. With product lifetimes on the decline due to rapidly changing technology, the increased demand for product safety and quality, and changing market conditions, the life of production equipment based on hard automation can exceed that of the product being produced. Therefore, there is a need for flexibility as well as automation in production. Because automated systems with controls based upon intelligent electronics can be re-programmed to produce a variety of generic products, it has come to be known as 'flexible automation'.

Flexible automation not only helps to meet the challenge of shorter product lifetimes, but also makes feasible the automation of batch production facilities. Products produced in batches are usually done manually because the volumes of individual products are too low to justify hard automated equipment. However, if the equipment can be reprogrammed to produce a number of similar products it becomes much easier to generate the volume of business required to justify the costs of automation. Therefore, as programmable electronics are introduced to batch production facilities, the production costs of an increasing number of low volume products will decline.

While the current high unemployment rates in most of the industrialized countries make it hard to appreciate, a further factor behind the trend to automated manufacturing is the shortage of workers. At the top end of the skill scale there is a shortage of designers, machinists, tool and die makers, and related trades. Advances in Computer Aided Design/Computer Aided Manufacturing (CAD/CAM) have made possible huge increases in the productivity of these skilled workers.

At the other end of the skill scale, it has become increasingly difficult to attract workers for non-skilled manufacturing jobs if they involve boring, heavy, or dangerous work. Such jobs are often better done by robots or other automated systems. The trend towards automation of low skilled jobs is reinforced by health, safety, and quality of work life issues.

Given the availability of the technology, the need to improve productivity, the need for flexible manufacturing systems and the shortage of workers, why has the diffusion rate of CAD/CAM technology been low?

Perhaps the most pervasive reason is that, at least until recently, there was little perceived need for change amongst management of manufacturing facilities. Other reasons that are often mentioned include:

- Shortage of capital for investment in facilities and equipment.
- A lack of awareness of the new technology on the part of management.
- The conservative nature of manufacturing management, i.e. a preference for proven technology.
- Concern over labour displacement and other social impacts of automation.
- Need to retrain workers.
- Resistance to change amongst middle management.

The list could go on, but the point is that the market for CAD/CAM equipment is clearly not driven by the availability of technology. It has, historically, been a market where vendors of the equipment have had to convince management that it is to their benefit to automate parts of their

plants. The degree of resistance to new technology has been so great that it has not been unusual for vendors to have to demonstrate a pay-back period of one to two years for equipment, such as robots, that has a service life of seven to eight years.

There are parts of the market that will undoubtedly continue to develop as they have in the past. But as the more fundamental desire to survive in world markets overtakes managements' resistance to change, manufacturing management is increasingly taking the initiative to acquire new technology. The commitment to automation is so large that buyers are shopping the world in order to get the best equipment for their needs.

In the sections that follow, we will examine the role of microelectronics in manufacturing, the markets for CAD/CAM equipment and the opportunities for Ontario manufacturers of CAD/CAM equipment.

## Role of Microelectronics in Manufacturing

New developments in automated manufacturing have become virtually synonymous with new developments in CAD/CAM technology. With the exception of a few discrete products such as computer-based drafting systems, numerical controls, and robots, suppliers of CAD/CAM equipment do not comprise an established industry in the sense that they supply a set of proven products to meet well defined needs. The common element amongst them is the application of programmable electronic devices to some portion of the design or manufacturing process.

The definition of computer assisted design is (any) 'process which uses a computer to assist in the creation or modification of a design'(2). The most common application of CAD is for automated drafting systems consisting of a graphics terminal, computer system for processing and storing data, a printer or plotter for hard copy, and an applications' program. Using the system a designer 'draws' a diagram on the video terminal and the information is stored in a data base, instead of as a line drawing on paper. The data base can be accessed to produce a numerical control tape, for finite element analysis, simulation or other analytic purposes.

A CAD system enables a designer to quickly and easily change a design, perform sophisticated analyses on it and then compare the results to the previous designs. This procedure can be repeated until an optimal design is achieved. The techniques used can, theoretically, be carried out by hand, but it would take several lifetimes to carry out the calculations that the computer performs in a few minutes. Thus, a CAD system can provide the designer with powerful new design techniques while improving his/her productivity.

CAD systems are used extensively for integrated circuit and printed circuit board design. They are also used for cartography, mechanical design, structural design, and virtually every other design function that involves drawing figures on paper. The system hardware does not vary significantly from application to application, but each requires its own software

package. Applications software is generally supplied by the hardware vendor as part of a 'turn-key' installation. Where custom software is required its cost can exceed the cost of the hardware.

One of the fastest growing areas of computer assisted manufacturing is the use of robots to perform functions that were previously done manually or by hard automation. Robots are used for welding, spray painting, materials handling, and assembly. They are finding rapid acceptance in environments where: objects are too large or too heavy for human operators; the frequency and accuracy of operations is beyond human capability; or work conditions are a threat to health and safety.

The control system of robots is based upon programmable electronics and it is the programmable feature that makes them attractive as a replacement for hard automation. Robots can be programmed to handle different products on the same production line. Hard automation is dedicated to a single product and must be discarded at the end of the product lifetime. Robots are simply re-programmed.

Most of the robots currently in use do not have any adaptive controls; that is, they are not capable of collecting data, processing it, and then acting accordingly. Instead they are programmed to move to a precise location, perform a function and then either repeat the process or perform a different task, depending on the program instructions. The reliability and economic advantages of this generation of robots has been proven and their numbers are growing rapidly in welding, painting, and material handling.

Much of the current robotics research is focused on adaptive controls. It is highly desirable to provide robots with rudimentary forms of sight and touch so that they can be programmed to react according to what they 'see' and 'feel'. Advances in the state-of-the-art in these areas will make more and more assembly operations by robot feasible.

Robots with sensory capabilities will require more sophisticated computers and software than the current generation of robots.

The most mature CAM technology is numerical controls (NC). An NC system accepts programmed information from a punched tape or other medium. The information is transformed into signals which are used to drive motors and other actuators that produce the desired motion. Most current NC systems are microprocessor based and are referred to as computer numerical control (CNC) systems. An on again, off again area of research is direct numerical controls (DNC). In a DNC system program information is stored in a computer rather than on paper tape. A major source of problems with NC systems has been with the tape reader. With advances in DNC technology, the tape reader (and its problems) can be eliminated. As well, DNC systems can more easily be interfaced with distributed or hierarchical computer controls.

Numerical controls are most commonly found on metal removal and forming machine tools. The portion of the electronics cost of NC machine tools has

fallen from 50 per cent in 1968 to less than 15 per cent currently. As the price has declined NC machine tools have gained rapid acceptance. They are usually process specific rather than product specific and are most commonly found in batch production environments. Parts can be produced at faster rates, more accurately and with greater consistency with numerical controls than with manually operated machine tools. When production of a batch of specific parts is completed, the program for the next part is supplied to the machine tool.

In the decade since their introduction, programmable controllers have become a staple component of manufacturing control systems. The main components of a programmable controller (PC) are the processor module and an input/output (I/O) subsystem. The processor module contains the central processing unit (usually microprocessor-based), the memory, power supply and peripheral devices. The I/O subsystem receives feedback signals from sensors which are, in turn, processed by the central processing unit. Control signals are then sent through the I/O subsystem to solenoids, motors, or other actuators which perform the desired tasks.

Programmable controllers have a wide variety of applications in automated manufacturing, from control of single machines to controlling the sequence of operations on an assembly line or a transfer line. When supplied with the appropriate data communications equipment, PCs can be interfaced with other PCs, robots, NC machine tools, remote I/O devices and computers. The ability of control systems based upon intelligent electronics to communicate with each other has led to a move away from stand alone computer assisted machines and systems to integrated manufacturing systems under hierarchical control.

In many applications of microprocessor based systems the manufacturing process does not change dramatically. In some instances the emphasis is on equipping machines to run for long periods of time without attention. This not only reduces the amount of labour required, but also results in benefits such as reduced raw material consumption, better product quality and improved productivity. For example, robots can be used to load and unload CNC machine tools. The process can be sequenced by a programmable controller which can also monitor things such as tool wear, machine downtime, parts produced, number of rejects and other variables of interest.

In other applications the programmable capabilities of PCs and computers are exploited to provide flexibility. Until recently most controls for transfer lines and assembly lines were based on relay systems and limit switches. Now programmable controllers are commonly used, making it much simpler and cheaper to intermingle products and to re-tool at the end of the product life.

Flexible manufacturing systems, automated material handling, and automated inspection are examples of emerging technologies that have been made possible by advances in microelectronics. Flexible manufacturing systems consist of groupings of general purpose NC machine tools that are connected by an automated material handling system. The entire system is under the supervision and control of one or more computers.

In a typical automated material handling system, data on incoming raw materials and parts is fed into a computer, either manually or through a bar code reader. The computer updates inventory records, determines a storage location and instructs pallet carriers, cranes or conveyors as appropriate, to store the incoming items. Programmable controllers are used to control the various parts of the system and to track movement of the parts. The system can be interfaced with a production scheduling system, in which case the computer would issue instructions for parts retrieval.

Automated inspection systems based upon computer and PCs are used for both dimensional and functional checks of products. Automated inspection allows for 100 per cent inspection in many cases where spot checks are only feasible using manual methods. This not only results in better quality, but by monitoring data on the number of rejects, production problems can be quickly spotted and corrected.

As the individual CAD/CAM technologies mature, a major challenge will be to join them into integrated manufacturing systems. This will require the development of standards for interfaces and data communications. While the state of the art of hardware is advancing rapidly, lags in software development may hold back full exploitation of CAD/CAM techniques. Development of high level software and computer languages are needed for greater efficiency, for interfacing and co-ordinating machinery and for man-machine interaction.

## Market Size

In 1980 Canada's consumption of machine tools was $471 million. With production at $175 million, the 1980 deficit in machine tools was close to $300 million. Accurate figures are not available on what portion of the machine tools sold in 1980 were equipped with numerical controls, but a reasonable estimate would be 15 to 20 per cent. These figures point towards substantial import replacement opportunities for Canadian manufacturers but they tell only part of the story. Virtually all numerical controls, programmable controllers, robots, and industrial computers consumed in Canada are imported. While the total Canadian market for electronic-based manufacturing equipment is large there are several reasons why prospective entrants to the market should not depend upon it for a major or even significant portion of sales.

The first is that the Canadian market is highly fragmented. The market for individual products is too small to provide economies of scale. Other reasons for looking beyond the Canadian market are:

- Subsidiaries and agents of foreign manufacturers are well established in Canada. New entrants would have to compete with them for a share of a small market.

- There are few Canadian-owned firms large enough to support large investments in automated manufacturing.

For these reasons and others Canadian manufacturers of CAD/CAM equipment must operate in markets outside of Canada in order to be successful. Given its size and proximity, the United States is the logical market for Canadian manufacturers to consider.

The largest single market for CAD/CAM equipment is the United States. It is the world's largest producer, consumer, and importer of machine tools. In 1980 consumption of NC machines was 11,000 units, up 57 per cent from the 1979 figure of 7,000. Imports into the United States in 1980 totalled 4,000 units. Factory shipments of nearly 8,000 NC machine tools in 1979 were valued at more than $1 billion. Electronics accounted for 31 per cent by value of cutting machines and 8 per cent by value of forming machines (10). The increase in demand for NC machine tools in the last year or two would suggest that United States industry has started to make the large investments that are generally accepted as being necessary to reindustrialize that country. For other CAD/CAM equipment the United States is either the largest or second largest market (after Japan) in the world.

The automotive industry is the largest consumer of machine tools and is expected to remain so through to 1985. Over 55 per cent of the world's industrial robots are employed in the automotive industry. The largest market for automated material handling equipment is also the automotive industry. Despite the recent poor sales and record losses of the United States automakers, demand for automated manufacturing equipment will remain strong since it is one of the key elements in their strategy to regain competitiveness.

A second major market for CAD/CAM equipment is the aerospace industry.

Other markets include manufacturers of consumer durables, electrical/ electronics products, machinery, and metal parts.

Demand for machine controls is expected to remain strong. Sales of programmable controllers grew by about a third from 1979 to 1980 to $202 million and, according to the trade publication Electronics, should increase a further 28 per cent in 1981. Projections by the machine tool industry indicate that by 1985 about 50 per cent of the machine tools ordered will have numerical controls. An integral part of machine controls is speed and torque controls for electrical motors. As the demand for automated manufacturing systems grows so will the demand for motor controls.

Table 1, below, contains estimates for machine controls and other electronics hardware used in CAD/CAM equipment. It should be noted that, while the forecasts in Table 1 are for the industrial market, not all of the products will go into automated manufacturing systems.

The fastest growing sector of the industry supplying automated manufacturing equipment is robot manufacturers. In 1980 the U.S. robot industry's sales were about $90 million. The expected growth rate for the next decade, most

commonly mentioned in the trade press, is 35 per cent per year. If that rate is achieved industry sales by 1990 will exceed $2 billion per year. Projections by Frost and Sullivan Inc. for the worldwide market show slightly slower growth. However, the projections for the automotive industry have proven to be far too conservative and indications are that estimates for other markets may be low as well. The Frost and Sullivan Inc. projections are contained in Table 2.

Computers of all types (mainframes, minis, micros) are used extensively in automated material handling, assembly, and inspection systems. As the demand for the automated systems grows so will the demand for computers. However, since these types of systems are usually custom designed and the computers used can, with minor changes, be used in many other applications, forecasts for the entire computer market do not accurately reflect the demand for computing hardware for manufacturing systems. While it is not possible to determine the portion of the electronics cost, the figures in Table 3 give some indications of the expected growth of the market for automated manufacturing equipment.

The projections in Table 3 are a little dated and individual figures are probably not accurate. For example, the robot market will be about three times as large in 1982 as the $45 - 56 million shown in the table. At the time that the projections were prepared, the United States economy was relatively strong, competitiveness was not a major issue, and the word reindustrialization was not commonly used. Since then the level of investment for automated manufacturing has increased and the roughly 15 per cent annual growth rate indicated by the Arthur D. Little, Inc. figures is probably conservative.

To summarize the discussion on the size of markets for Canadian manufacturers of CAD/CAM systems, it seems clear that they must look beyond their backyard to the United States, and ultimately the world markets, to sell their products. There they will find very large and rapidly growing markets for all types of CAD/CAM equipment.

## Suppliers of CAD/CAM Equipment

Historically, suppliers of manufacturing machinery have catered to national or even regional markets. The strategy worked well enough at a time when the technology of the machinery was relatively static. In the current climate of rapid change, the advantages to be gained by seeking the most technically advanced equipment has prompted buyers to evaluate all available competitive equipment. This trend towards worldwide sourcing is reinforced by the large size of the financial commitment being made by companies to automated manufacturing and management's desire to get the best possible return on the outlays.

As the supply industry grows and matures, new products and suppliers will emerge. Joint ventures, licensing agreements, agency relationships and the like will develop as leaders in their respective fields compete for markets beyond their national boundaries. As much of the CAD/CAM equipment is in

its embryonic stage of development, the structure of the supply industry will remain in a state of flux for some time.

Not surprisingly, suppliers of products based upon mature technology have an identifiable structure while those supplying products incorporating new technology have a less well-defined structure. In the section that follows we will have a brief look at the suppliers of various types of CAM equipment.

Numerical controls is the most mature CAM technology and the United States market is dominated by a small number of major suppliers. General Electric is the largest, by far, with 38 per cent of the market in 1977. Other major suppliers, in order of size, are: Cincinnati Milacron, General Numeric Corporation, Allen-Bradley, Bendix Corporation, Bridgeport Machines, Kearney & Trecker Corp., Warner & Swasey, and Giddings & Lewis, Inc. There are a further dozen or so smaller United States based suppliers. Most of the suppliers also manufacture related products such as machine tools, transfer lines, programmable controllers, robots, and the like.

With the exception of General Numeric Corporation all of the major NC suppliers in the United States are domestically owned. General Numeric Corporation is a joint venture of Fujitsu Fanuc of Japan and Siemens of West Germany. It was originally established as a marketing subsidiary but is, apparently, moving into manufacturing. General Numeric Corporation is the fastest growing supplier of NC systems in the United States.

The United Kingdom, France, Germany, Japan, Sweden, Italy, the Netherlands, Norway, and Switzerland have one or more producers of NC systems.

There are no manufacturers of numerical controls, and only two or three manufacturers of NC equipped machine tools, in Canada. Several of the major United States suppliers -- notably, General Electric, Cincinnati Milacron, Allen-Bradley, and Bendix Corporation -- have Canadian subsidiaries. While some of them manufacture in Canada, none produces numerical controls here.

There are more than 30 robot manufacturers in the United States and the number is growing. At the ROBOTS IV Conference and Exhibition in Detroit in 1980 five new entrants to the field displayed their products. The largest robot manufacturer is Unimation Inc. With sales of $42 million in 1980, Unimation claimed almost half of the United States market. There being so many manufacturers to share the rest of the market, it is clear that many of them are quite small. It would seem that the attraction is the expected very rapid growth of the market. Indeed, giants such as IBM and Texas Instruments are reportedly weighing the prospects of entering the robot market.

Besides Unimation, major United States suppliers of robots include: Auto-Place Inc., Cincinnati Milacron, Prab, and General Numerics which markets Fanuc robots.

Several other countries are also active in the field. Japan has about 30 robot manufacturers. Fujitsu Fanuc markets its products in the United States, but the rest of the Japanese manufacturers operate mainly within their own country. France, West Germany, Italy, Sweden, Norway, and the United Kingdom each have at least one robot manufacturer.

With the exception of Spar Aerospace, the manufacturer of the remote manipulator for the NASA space shuttle, there are no Canadian companies manufacturing robots. (Depending on one's choice of definition, the remote manipulator is or is not a robot, but some of the technology may be applicable to industrial robots). All of the major United States manufacturers of robots, as well as several others, are represented in Canada by subsidiaries or agents.

At present, automated material handling, assembly, and inspection systems are custom installations designed around individual customer's needs. The industry supplying equipment for the systems contains a large number of diverse firms. While automated manufacturing systems will likely remain custom installations to some extent, a market is developing for companies that can provide entire systems. The firms that are best placed to take advantage of the market are those that are already manufacturing one or more of the products used in the systems. For example, manufacturers of automatic storage and retrieval systems, driverless pallet carriers, and electronics controls, would have obvious advantages when it comes to supplying automated material handling systems.

The rapidly growing Computer Aided Design (CAD) market is dominated by three United States companies. Computervision is the largest with a 35 per cent market share, followed by Applicon and Calma, each with 14 per cent of the market.

In Canada, three companies -- Omnitech, Phoenix Graphics and Cadais -- market CAD systems.

## Canadian CAD/CAM Market

As shown in Table 4 the Canadian market for CAD/CAM equipment was estimated at $61.9 million in 1979 and $91.5 million in 1980.

All items in the equation defining the size of the Canadian market grew rapidly between 1979 and 1980. As a result the share of the market held by imports remained at over 80 per cent despite a large increase in the amount of Canadian production.

The equipment produced in Canada is shown in Table 5.

Much of the increase in NC machinery production is due to the start up of a NC milling machinery manufacturer in Quebec. The $1.1 million of CAD

equipment shown for 1980 reflects the entry into the market of the three CAD system suppliers.

## Opportunities for Ontario Manufacturers

Although the level of manufacturing of CAD/CAM equipment in Canada is low, there is the potential to increase the level. The booklet Computer-Aided Design and Manufacturing in Canada lists over 70 suppliers of equipment and almost as many suppliers of consulting/design services. There are no fundamental reasons why one or more of these firms could not develop a significant manufacturing capability. However, firms entering the market can expect a great deal of competition.

The preceding discussion on the nature of the technology and the markets involved suggest that in order to be successful a prospective manufacturer must, as a minimum, have the following characteristics:

- Be willing and able to compete in United States and world markets.
- Must not only be able to supply quality products, but also be capable of providing the customer with necessary back-up services such as design and application engineering, adequate documentation, and training.
- To provide these services, the firm must have a strong presence, through a subsidiary, joint venture partner, or agent in the served markets.
- In a market that puts a premium on technology, a strong research and development capability or access to external research and development is an obvious necessity.
- Apart from being able to finance the production and marketing of the products, the firm must be able to finance extensive research and development before any returns are realized.

Looking at the electronics hardware used in CAD/CAM systems, where are the opportunities for Ontario manufacturers? The market for machine controls -- NCs, PCs, and motor controls -- is expected to grow rapidly, but in other ways it is a mature market. With no Canadian presence and virtually every other industrialized country active in the market, machine controls do not seem a good bet for prospective new entrants. There are about 15 manufacturers of mini and micro computers located in Ontario. Although their products could be used in manufacturing environments, most of them list their markets as office or business. Opportunities for them are discussed in the chapter on office automation equipment. This leaves CAD systems and robots, both of which may present opportunities for Ontario manufacturers.

Approximately 60 per cent of installed CAD systems are used for design of integrated circuits, printed circuits and other electronic components. The fastest growing segment is mechanical design.

Applications software is a significant part of CAD systems. Thus firms with strong software capabilities can gain a toe-hold in the market even if they do not manufacture hardware. The required hardware -- computers, storage, plotters, video display terminals -- can be bought off-the-shelf and a CAD system assembled. However, such a system would not necessarily be competitive, unless it offered some advantage over others that are available. In terms of hardware, product development efforts are focused on display technology. Therefore, from the standpoint of technological capability, firms with strong software and display technology have some advantage should they wish to turn their attention to the CAD system market.

Activity in the CAD field in Ontario appears to be restricted to marketing. There is at least one firm that markets design services using a CAD system and at least two others that market entire CAD systems. Much of the generic hardware used in CAD systems is manufactured in Canada. Software expertise and display technology capability is also available in Canada, but there are not any firms that are known to be bringing these elements together to produce CAD systems.

As noted earlier, the robot manufacturing industry is expanding rapidly in anticipation of very rapid growth in the market for industrial robots. There are many potential applications of robots, but much research remains to be done before they will be realized. There is a trend for robot manufacturers to specialize and to focus their research efforts on specific applications. With the expected rapid growth and the emphasis on product development, firms that come up with technical breakthroughs and translate them into products will be handsomely rewarded.

The largest current application of robots is welding car bodies. The biggest potential application is assembly, but advances in technology are required first. The areas of research that show the most promise for advancing the state-of-the-art of robot assembly are: vision, touch, and compliance (robots with compliant joints). Compliance is one of the areas pursued and developed by the Spar Aerospace and National Research Council (NRC) team that designed the remote manipulator for the NASA space shuttle.

With the expertise that has been developed at Spar, NRC, and other institutions, there is little doubt that Canada has the technical capability to enter the robot market. But technical capability is secondary to having the financial strength to perform research and development, build production facilities, and develop a marketing infrastructure before seeing a return. Some examples will serve to illustrate the point. Unimation Inc., the industry leader, cost its parent company, Condec, at least $12 million before becoming profitable in 1975. Government and industry in Japan reportedly spent $2 billion to develop industrial applications for robots (13). A new entrant, Automatix of Burlington, Mass. was founded in 1979 with $6 million from, amongst others, M.I.T. and Harvard.

While Ontario does have the nucleus of people to enter the CAD and robot markets as manufacturers, it is still a long way from doing so, primarily because the financial, production, and marketing resources are not

available. Finally, it should be noted that there are dozens of United States firms, not currently in the CAD and robot markets, that have the technical, financial, production, and marketing resources to do so. It is these firms, as well as those already in the market, with which fledgling Canadian companies must face the prospect of competing.

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Table 1

### U.S. MARKET FORECAST FOR SELECTED INDUSTRIAL ELECTRONICS

($ U.S. MILLIONS)

| | 1980 | 1981 | 1984 |
|---|---|---|---|
| Plotters | 121 | 154 | 198 |
| Graphics Terminals | 225 | 282 | 641 |
| Numerical Controls | 100 | 111 | 156 |
| Programmable Controllers | 202 | 259 | 401 |
| Motor Controls | 280 | 314 | 659 |
| Robots | 60 | 81 | 199 |

Source: ( 12 )

Table 2

### THE ROBOT MARKET INTO THE '80's

(1979 $ U.S. MILLIONS)

| | 1979 | 1981 | 1985 |
|---|---|---|---|
| Electrical Machinery | 15.8 | 41 | 164 |
| Automotive | 14.9 | 21 | 54 |
| Fabricated Metals | 16.5 | 26 | 67 |
| Electronics | 1.6 | 12 | 70 |
| Heavy Machinery | 12.2 | 19 | 13 |
| Others | 19.0 | 53 | 71 |
| TOTAL | 80.0 | 172 | 438 |

Source: ( 6 )

Table 3

### PROJECTION OF U.S MARKET FOR AUTOMATED MANUFACTURING EQUIPMENT

(CONSTANT 1977 $ MILLION)

| | 1977 | 1982 | 1987 |
|---|---|---|---|
| Numerical Control Systems | '120 | 139 — 195 | 217 — 338 |
| Automated Assembly Systems | — | — | 20 — 338 |
| Robots | 20 | 45 — 56 | 98 — 117 |
| Automated Material Handling Systems | 240 | 600 — 700 | 1,000 — 15,000 |
| Factory Floor Management Systems | 28 | 50 — 60 | 120 — 200 |

Source: ( 1 )

Table 4

### APPARENT CANADIAN MARKET FOR CAD/CAM EQUIPMENT

($ MILLION)

| ITEM | YEAR 1979 | 1980 |
|---|---|---|
| Production | 14.9 | 26.3 |
| — | | |
| Exports | 5.0 | 8.5 |
| + | | |
| Imports | 52.0 | 73.7 |
| = | | |
| Apparent Canadian Market | 61.9 | 91.5 |

Source: ( 11 )

Table 5

### CANADIAN CAD/CAM EQUIPMENT PRODUCTION AND SERVICES

($ MILLION)

| ITEM | YEAR 1979 | 1980 |
|---|---|---|
| NC Machinery | 8.4 | 14.0 |
| Spare Parts | 2.5 | 4.2 |
| Peripherals | — | — |
| Robots | — | — |
| CAD Equipment | — | 1.1 |
| Software | 4.0 | 7.0 |
| TOTAL | 14.9 | 26.3 |

Source: ( 11 )

AUTOMOTIVE ELECTRONICS

Less than a decade ago the phrase 'automotive electronics' was virtually synonymous with car radios. Other than a few semiconductors in the alternator and regulator all of the electronic components in an automobile were to be found in the radio or tape player. Gradually electronics found their way into ignition systems, emission controls, fuel systems and, more recently, dashboard displays. But it was not until the promulgation of emissions and fuel economy regulations that electronics began to have a major impact on the automotive industry.

Starting with the 1981 model year there will be a rapid increase in the number of vehicles equipped with microprocessor-based engine controls, where they help to meet mandatory (U.S.) emissions and fuel economy regulations. Also in the development stage to improve fuel efficiency are electronic controls for the transmission and intelligent electronic management of engine accessory load. With cars becoming smaller, electronic ride systems are also being developed to give them a luxury-car ride.

In the longer term (the late 1980s or early 1990s) electronics may become a significant part of safety systems. The development of this market will be largely determined by the presence (or absence) of safety standards. Some typical applications of electronics would be passive restraint control systems, collision avoidance radar, anti-lock brakes, and tire pressure monitors.

Even in the absence of government regulation as an impetus, enormous growth is expected in automotive electronics. The growth will occur in instruments, comfort and convenience features and entertainment products. Growth in these categories will partly come from the manufacturers' desire to attract buyers with electronic dashboards and accessories.

In addition, as microelectronic components become cheaper and more reliable, functions done mechanically or electrically will increasingly be taken over by electronics.

High fuel prices in European countries have precluded the need for fuel economy standards and none are expected in the foreseeable future. The European Economic Community countries have accepted the need for emissions standards, but none are likely to be implemented before 1985-86. Therefore, the European market for electronic engine controls will not be dependent on government regulation. Electronic engine controls may become fairly common within the next few years on engines with a displacement greater than 1.5 litres, but the production of such engines represents a small portion of the European industry's total. European and Japanese automobile manufacturers can, however, be expected to include some form of electronic engine controls on vehicles destined for the United States' market. The European market for

dashboard, convenience, and entertainment electronics can be expected to evolve in a manner similar to the North American market, but with a time lag.

In the early stages of growth of the market most of the action will be at the vehicle original equipment manufacturer (OEM) level. As the portion of the vehicle population that contains electronic systems grows a large market for replacement parts (after-market) will develop. A third market segment will be for service equipment to diagnose faults in the systems.

The market segment of immediate interest to prospective vendors of automotive electronics equipment is the North American OEMs. It will experience the earliest and most rapid growth. It will also remain the largest market segment until at least the 1990s. Automotive electronics are covered by the Canada-United States Automotive Products Trade Agreement (Auto Pact) giving Canadian electronics manufacturers duty-free access to the United States OEM market.

The United States tariff for automotive aftermarket parts is 3.8 per cent and 8.7 per cent for electronic diagnostic equipment.

## Size of the Market

The absolute size of the market for automotive electronics in 1985 or 1990, or at some other time in the future, is less important, from the point of view of identifying business opportunities and strategic issues, than the expectation that the market will grow very rapidly and be very large. Forecasts of the size of the various market segments depend upon a number of assumptions regarding vehicle production levels, diffusion rates of electronics systems, costs, and other factors. A number of estimates of the current and future size of the automotive electronics market have been published. Because of the different scope and assumptions of the forecasts they cannot be directly compared. Forecasts from three different sources will be discussed to illustrate the expected growth rate and potential market size.

Though it is now a little dated, the most comprehensive treatment of the subject was published by Arthur D. Little, Inc. in 1979. A summary of their forecast is shown in Table 1.

The estimates in Table 1 include the costs of sensors, actuators, wiring, connectors, and other components as well as the electronics. If only the cost of the electronic components is considered, the outlook would be as shown in Table 2.

The Arthur D. Little Inc. figures in Table 2 are within the same range as the forecasts published by the trade journal Electronics. The latter

publication does not include forecasts for Europe, but does contain an estimate for the current size of the Japanese market. A summary of the Electronics forecasts is shown in Table 3.

The last market forecast to be considered is for the worldwide market. It was prepared by TRW Inc. and is the forecast that is most often quoted in the automotive trade literature. A summary of the TRW Inc. forecasts is contained in Table 4.

Assuming that 25 per cent of the total subsystem cost is for electronics, that the average electronics cost per car is 50 per cent higher for United States built cars than for the worldwide average, and that 30 per cent of worldwide vehicle production will be in the United States, the TRW Inc. forecasts would indicate a United States market for electronic components of $1,134 million in 1985.

When the difference in the scope of the forecasts and definitions is taken into account, the three market outlooks are quite similar. They indicate a United States market for electronic components that will exceed $1 billion by 1985. If the entire electronics subsystems are considered, the size of the 1985 United States market will be $4 to $5 billion. The primary market for Canadian suppliers will be the United States. While diffusion of electronic subsystems in automobiles manufactured in Western Europe and Japan is expected to lag, the United States and Canada will represent a significant secondary market.

Over one-half of the cost of the electronics package on cars will be for engine and drive train controls. For the 1981 model year, electronic controls are being installed on all General Motors cars with gasoline engines; all Ford Motor Company models except the Escort and Lynx; and all Chrysler cars except those equipped with 2.6 litre or 3.7 litre engines, and some 'Canadian' models. Under existing United States fuel economy and emissions legislation, it is a reasonable assumption that all of the cars sold in the United States after 1985 will have electronic engine controls. However, the future is made uncertain by published reports that the Reagan Administration is planning to relax fuel economy, emissions, and safety standards.The dependence on regulation of this market makes it a high risk environment.

Fully electronic instrument panels, digital search tune radios, keyless entry systems, speed regulators and other 'feature electronics' are available as standard equipment or options on top-of-the-line models. If the normal pattern of diffusion of innovation is followed, the electronic systems will soon become standard equipment on top-of-the-line models and optional equipment on cheaper models. As prices drop and the new systems gain consumer acceptance, they will become standard equipment on more and more of the lower-priced models. Most observers believe that feature electronics will be the growth area for automotive electronics. By 1985, the size of the feature electronics market could easily exceed that of electronic engine controls. The development of the feature electronic

market will depend upon consumer acceptance and, given the current low diffusion level, estimates of the future size of the market may not accurately reflect the manner in which the market develops.

With virtually all of the electronic systems installed by OEMs being new, there are few field data from which to estimate failure rates and maintenance costs. The aftermarket for electronic components will start to develop in earnest in 1983-84 when the number of electronic systems that have been in service for a few years becomes large. The market will continue to grow after that, but it will not be possible to accurately estimate its growth rate until better estimates of diffusion rates and maintenance costs are available.

What is more certain is that some segments of the after-market will decline and eventually disappear. Much of the market for tune-up parts will disappear. Mechanical distributors along with their contact points, condensers, and rotors will become obsolete. Spark plugs will still be used, but their service life will increase. Carburetor technology is changing rapidly and as throttle body fuel injection becomes more popular, manufacturers of tune-up carburetor kits will be looking for new markets, or going out of business. The growth areas will be for semiconductor components, sensors and actuators.

The huge number of new electronic systems on cars will have a profound effect on the service industry. There will have to be a very large investment in training of service personnel and some additional investment in diagnostic equipment. However, the amount of diagnostic equipment that is needed will not be as much as first expected and the forecasts for service equipment contained in Table 1 are probably too high. Self-test hardware and self-test software built into the systems can reduce or eliminate the need for external diagnostic equipment. The General Motors Computer Command Control system (engine controls) is largely self-testing and requires little outside diagnostic equipment. Ford's Micro-processor Control Unit (MCU) requires a relatively simple and inexpensive device called a Self-Test Automatic Readout for testing system malfunctions. Building self-testing capability and redundancy into the systems is expensive and increases the development time required. Chrysler has gone the other route. Its electronic engine controls have no self-testing features and must be connected to an Electronic Engine Performance Analyser (EEPA) for diagnostic tests. The EEPA is a far more sophisticated piece of equipment, but at $16,500 per unit represents a considerable investment for service establishments.

In the next few years, on-board, self-monitoring and self-testing systems are expected to become universal. As that occurs, growth of automotive electronic systems will cease to have a significant effect on the service equipment market.

## Nature of the Market

Electronic component manufacturers that wish to supply the automotive industry face significant problems that are absent or not as pronounced in their traditional markets. The engine compartment is an extremely hostile environment for electronics. Typical specifications for under-hood components include a temperature range of -40° to +85° C. OEMs demand very high reliability and very low cost which, of course, are incompatible. These are merely technical problems. Once they have been overcome, semiconductor companies must be willing to abide by Detroit's rules of the game if they wish to participate in the OEM market.

The rules of the game include:

° Suppliers must make the necessary capital investments to meet volume and quality levels without any guarantee of holding the job or of follow-on business. While automobile manufacturers take vendor capital commitments into account when purchase contracts are placed, releases may deviate widely from initial schedules leaving a supplier with underutilized production capacity.

° The automobile manufacturers will often produce 50 per cent or more of a given part and purchase the rest from one or more outside vendors. In a cyclical downturn, some manufacturers pull jobs in-house or move them to a competitive vendor; others allocate the remaining business in accordance with contract percentages.

° Profit margins are very low on OEM parts. Increases in the cost of raw materials are difficult to pass through. Prices paid to vendors are based upon long run production costs; not start-up costs.

° Because the operations of their assembly lines depend on a steady and reliable supply of parts, OEMs require and demand primary attention and commitment from their vendors. This aspect is becoming more critical as OEMs cut inventory levels to reduce cost and become more and more dependent on frequent deliveries from their vendors for their day-to-day requirements. This greatly constrains a supplier company's ability to participate in other markets, including the automotive aftermarket.

The commitment to electronics has been so great that all of the major North American automobile manufacturers have developed in-house research, development, and design capability in electronics. Two of them, General Motors through its Delco Electronics division and Ford Motor Company through its Electrical and Electronics Division, also have semiconductor manufacturing capability.

The current generation of electronic engine controls are largely designed around off-the-shelf semiconductor components. These systems were mainly developed in-house by the automobile manufacturers and the semiconductor manufacturers acted primarily as component suppliers. These systems are capable of meeting fuel economy and emissions regulations through to 1985 and the current research and development efforts are aimed at systems with more self-diagnosing features, better reliability, and lower cost.

One of the routes being taken to reduce costs is to increase the use of custom large-scale, integrated (LSI) circuits. This has led to closer collaboration between the automobile and semiconductor manufacturers during the design stage. For example, the General Motors Computer Command Control (CCC) system used on its 1981 model cars is based on a Motorola 6802 8-bit, off-the-shelf microprocessor. A later version, the General Motors Custom Microcomputer which will replace the CCC in the 1982 model year, contains a custom chip set developed in co-operation with Motorola. The two-chip system that Ford will use in its EEC IV system for installation on 1984 models was developed jointly by Ford and Intel Corporation.

Many of the large semiconductor companies, including Motorola, Toshiba, Essex, R.C.A. and Intel, have been active in the electronic engine controls market. As the market develops, Motorola and Intel are emerging as the dominant factors in the market after the automobile companies themselves. Motorola has a long established relationship with the automotive industry as a supplier of alternators and radios. Intel is a relative newcomer to the automotive OEM market.

The market for sensors is divided amongst the automobile companies, semiconductor industry and instrumentation industry. Texas Instruments, Robertshaw Controls, and Eaton are all active in the automotive sensors market.

The relays, solenoids, electric motors and other actuators used in automotive electronic systems are largely designed in-house. Actuators, along with connectors, wiring, packaging and other bits and pieces are either made in-house or by independent parts manufacturers to OEM specifications.

In the intitial stages of development of the aftermarket, the automobile manufacturers will be a major source of replacement parts. They have a monopoly on parts replaced under warranty. As the population of out-of-warranty vehicles equipped with electronic systems grows the automobile manufacturers will remain a dominant influence in the aftermarket. The major source of replacement semiconductor components and sensors will continue to be the automobile companies. The aftermarket for the simpler components will develop in the conventional way with participation of both the OEMs and independent parts manufacturers.

The market for electronic service equipment is dominated by a few United States companies. Sun Electric with annual sales of more than $100 million is the largest manufacturer of engine diagnostic systems. Other companies active in the market are Allen Test Products, Marquette, and FMC Corporations's Automotive Service Equipment Division. These companies will benefit from any near term market growth, but as the growth will be modest and is not expected to be sustained, the market will not be able to support any new entrants.

Ontario's Position

The Ontario automotive electronics industry is comprised, in the main, of three companies, all of which are subsidiaries of United States multinational corporations. They are as follows:

- Philco-Ford of Canada Limited, Don Mills. The plant is the sole source of most of the electronic components, except engine controls, that Ford Motor Company uses on the motor vehicles it builds in North America. The products manufactured at the Canadian plant include: digital search radios, electronic dashboard displays, and graphic display failure monitors.

- TRW Canada Ltd. Automobile radio tuners are produced at a plant in Toronto. Automotive relays, solid-state devices, timers and other electro-mechanical devices are manufactured at the TRW, United-Car division, in Brantford.

- Sprague Electric of Canada Ltd., Toronto, supplies capacitors to the Delco division of General Motors.

Two other large United States based electronics manufacturers have operations in Ontario, but neither manufacture automotive electronics equipment, as such, at their Ontario plants. Motorola Canada Ltd. manufactures two-way radio equipment at its Willowdale plant. Essex International Canada Ltd. assembles automotive wire harnesses at St. Thomas.

There are other, smaller, Ontario companies involved directly in the automotive electronic market.

The two largest consumers of automotive electronics, General Motors and Ford, have captive suppliers that are responsible for meeting corporate requirements of electronic systems. They are Delco and AC, in the case of General Motors, and Ford Aerospace Communications Corporation, in the case of Ford. The structure of the market leaves little room for manufacturers of complete systems, but there are substantial opportunities for suppliers of semiconductor components to the electronics divisions of the automobile manufacturers.

With the exception of Sprague Electric of Canada Ltd. there are no Ontario semiconductor companies supplying the automotive market. Despite Philco-Ford of Canada's substantial volume it has not been able to source any of its sophisticated electronic components in Canada. However, considerable effort is being made to develop Canadian sources of supply. Integrated circuits and other sophisticated components come, primarily, from low wage-rate countries such as South Korea. Under the multilateral provisions of the Canada/United States Automotive Products Trade Agreement (Auto Pact) the components enter Canada duty-free. Some metal stampings and plastics components, made to the buyer's specifications, are sourced in Canada.

Of the three major automotive electronics firms in Ontario, Philco-Ford of Canada Ltd. is by far the largest. It currently employs 170 people in its office and 780 in the plant with plans for an additional 200 employees. The products are designed at facilities in Detroit, but the Ontario plant has responsibility for manufacturing engineering.

As the sole supplier to the Ford Motor Company of the products manufactured by Philco-Ford of Canada Ltd., the growth of the Ontario operations depends heavily on the level of customer acceptance of automotive electronics. At present, roughly 85 per cent of the plant's output is destined for the luxury end of Ford's model line. If the automotive electronics market develops as rapidly as the earlier discussions on markets would indicate, Philco-Ford of Canada will grow rapidly to meet the demand.

Canadian electronics companies that wish to become suppliers to the automotive companies have, through the Auto Pact, duty-free access to buyers in the United States. While the market is very large, it has become dominated by a few of the industry giants. Amongst the leaders are Motorola and Intel. Motorola is not only one of the largest electronics companies in the world with 1980 sales of $3.1 billion, but also is a longtime supplier to the automotive industry. Intel developed the first microprocessor in 1971 and has had a consistent record of innovation ever since. The implications for new entrants are obvious. Their best prospects are in areas in which the giants have no interest.

In a general sense, any prospective supplier to the automotive OEM market must be able, and perhaps more importantly, willing to play by Detroit's rules of the game. A buyer such as Philco-Ford of Canada Ltd. might look for the following in a chip supplier:

- Technical capability in both product design and manufacturing engineering.
- The ability to spend $0.5 to $1.5 million on product development with no guarantee of a return on the investment. For products with a high degree of sophistication, development costs could be much higher. Once the design has been completed, the lowest bidder, not necessarily the company that financed the development, would be awarded the contract.
- State-of-the-art production facilities and processes that minimize the number of defects.
- A sound quality control department. Buyers are demanding that more and more of the testing be done by the supplier. When quality problems occur the supplier must be able to react very quickly.

The requirements, in effect, limit entrance to the market for the more sophisticated semiconductor components to all but a handful of Canadian companies. As more of the small companies grow to the point that they can support fairly extensive research and development, manufacturing, and quality control operations, they will be in a better position to compete in the automotive electronics market.

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Table 1

AUTOMOTIVE INTELLIGENT ELECTRONICS
MARKET FORECAST SUMMARY

(MILLIONS OF 1978 $ U.S.)

| | 1978 | 1982 | 1987 |
|---|---|---|---|
| U.S. MARKET | | | |
| Drivetrain | 10 — 15 | 1000 — 1300 | 1100 — 1900 |
| Dashboard | 3 — 5 | 500 — 600 | 1500 — 3000 |
| After-Market | — | 75 — 100 | 1000 — 1700 |
| Service Equipment | 150 — 170 | 180 — 200 | 220 — 240 |
| TOTAL | 160 — 190 | 1800 — 2200 | 3800 — 6800 |
| EUROPEAN MARKET | | | |
| Drivetrain | — | 150 — 400 | 600 — 700 |
| Dashboard | — | 350 — 500 | 600 — 700 |
| After-Market | — | 25 — 30 | 600 — 750 |
| Service Equipment | 60 — 90 | 80 — 100 | 100 — 120 |
| TOTAL | 60 — 90 | 600 — 1000 | 1900 — 2300 |

Source: ( 1 )

Table 2

AUTOMOTIVE MARKET FORECAST
FOR ELECTRONIC COMPONENTS

(MILLIONS OF 1978 $ U.S.)

| | 1982 | 1987 |
|---|---|---|
| U.S. Market | 497 | 1,026 |
| European Market | 236 | 292 |
| TOTAL | 733 | 1,318 |

Source: ( 1 )

Table 3

AUTOMOTIVE ELECTRONICS MARKET FORECAST

(MILLIONS OF $ U.S.)

| MARKET | 1980 | 1984 |
|---|---|---|
| United States | | |
| Engine control systems | 234 | 484 |
| Electrical systems | 26 | 34 |
| Convenience features | 50 | 149 |
| Safety and Security | 17 | 151 |
| Dashboard | 82 | 211 |
| Diagnostic Equipment | 300 | 420 |
| TOTAL | 709 | 1449 |
| Japan (TOTAL) | 251 | |

Source: ( 2 )

Table 4

WORLDWIDE MARKET FORECAST FOR AUTOMOTIVE ELECTRONICS

| SUBSYSTEM | PRICE RANGE PER UNIT ($ U.S.) | COST PER CAR ( MILLIONS $ U.S.) 1980 | 1985 |
|---|---|---|---|
| Electrical | 2 — 30 | 6 | 9 |
| Instrumentation Display | 15 — 250 | 4 | 33 |
| Drivetrain Control | 12 — 200 | 27 | 152 |
| Comfort and Convenience | 3 — 60 | 6 | 24 |
| Safety and Security | 3 — 150 | 2 | 22 |
| TOTAL | — | 45 | 240 |
| No. of Vehicles (millions) | — | 35 | 42 |
| Market Size (millions) | — | $1,575 | $10,080 |

Source: ( 5 )

## ELECTRONIC CONSUMER PRODUCTS

### BACKGROUND

#### Introduction

Perhaps in no other field has the application of integrated circuits (i.e. microprocessors) been more obvious and pervasive than in consumer goods. The application of microprocessors has not only transformed the nature of traditional products, such as watches, but has also led to the creation of entirely new products such as hand-held calculators. Both of these microprocessor applications offer instructive case studies of the way things will develop in the 1980s, when the major growth areas are likely to be those products with specific chip applications as in toys, games and home computers. It is estimated that the rate of change in consumer electronics will be such that by the early 1980s, the sale of new chip-based products in the U.S. will surpass that of traditional electronic products such as TVs, radios and hi-fis (1). These new products will not necessarily replace existing consumer goods, but will create new primary demand, thereby competing for disposable income with other household products and services.

In dealing with the subject of intelligent electronic consumer goods, it is necessary to define the term chip or microprocessor. These terms are used broadly by industry to describe a wide range of programmable devices with varying power and capability. The key attribute of the microprocessor, and the reason that it qualifies as "intelligent" electronics, is its programmability. Any product that currently relies on an electro-mechanical device to relay information can be transformed by microprocessors to increase its reliability, versatility and efficiency.

Table (1) shows some applications of integrated circuits (IC) chips. Most ICs, and especially digital circuits and memories, are used in computers, but a large and growing number are currently going into consumer products, particulary entertainment products. About 38.8 per cent of all ICs produced in 1980 were utilized by such products (entertainment products, clocks and watches, and domestic appliances). On the basis that 5 per cent of a product's value is made up of IC chips, the current world market for chip-based products (all types) is $180 billion and growing at 12 per cent annually (2).

#### Consumer Applications

Table (2) offers a partial list of the variety of uses of a single multi-purpose microprocessor developed by Texas Instruments (TMS 1000). The read-only memory (ROM) requirement refers to the length of program (in 8-bit words) needed to realize any particular application. This same basic chip can be programmed to perform a number of different functions.

With the rapid utilization and diffusion of chip-based products in the home, it has been estimated that the average American home will accumulate, through various products and services, close to 1 million bits of memory and

logic by 1990. Figure 1 estimates the growth and pervasiveness of chip technology at the consumer level if current trends continue.

However, these projections are based on existing applications with current technology. Many existing products and services have yet to be affected by microprocessors and the potential for improving existing consumer products is far from being fully exploited. The faster IC chips are utilized, the more applications they generate. Further applications will depend on chip technology advances, especially interface technology which will lead to talking, seeing and doing machines such as robots.

## CONSUMPTION & PRODUCTION

### World Trends

The U.S. is currently the single largest consumer of chip-based products in the world and it is expected to maintain that position over the next decade. By 1987, it has been estimated that U.S. consumption levels for chip-based consumer products will be 279 million units compared to 128 million units for the combined consumption levels of France, West Germany and the U.K. (Table 3).

One of the major reasons for the U.S.'s heavy consumption of IC chip-based products is that country's dominance in the production of integrated circuits. It has been estimated that by 1982 the U.S. will produce approximately $13 billion worth of the world's $17.4 billion supply of ICs, and consume about 43 per cent of total world production (5).

### Calculators

Even though the U.S. is the world leader in the total production of chip-based consumer products, this is not necessarily the case for individual goods. By 1976, Japan was dominating the assembly of cheap personal calculators, accounting for 40 million units of the 50 million units produced world-wide. Of the other 10 million, the U.S. accounted for 7.5 million and Western Europe for 2.5 million. However, the U.S. market had remained the largest, accounting for nearly 50 per cent of world sales (2). The world's largest supplier today is the Japanese electronics firm Casio, followed by Sharp, the next largest. Texas Instruments is the only major U.S. semiconductor company left in the calculator business, maintaining a strong presence in higher-priced calculators.

### Watches

In the world watch market, Japan has now become the second major source of watches after Switzerland. The general shift in electronic watch production, since 1970, has been from the U.S. and Europe to Japan, Taiwan and Hong Kong. Japan now accounts for 47 per cent of the world's production of electronic watches (2).

Toys and Games

Toys and games have been completely transformed by the microprocessor. This sector was virtually created by the Americans and is still dominated by the U.S. The world market for electronic toys and games for 1979 was $1 billion with the U.S. accounting for 84 per cent of sales (2). Unlike calculators and watches, toys and games have remained in the control of traditional producers.

In a market that is only 6 years old, there are already 60 million units sold in the U.S. with anticipated sales worth $900 million for 1981, up from $15 million in 1975. Mattel Inc. expects sales increases of 20-40 per cent over the next 2-3 years (6).

Texas Instruments has established itself as a key supplier of chips for the games and toy market. In 1979, approximately 70 per cent of the 9.4 million ICs (TMS 1000) produced by Texas Instruments were used in the production of games and toys (2).

The second generation of games will fall into one of three major categories:

- video games,
- hand-held arcade games; pinball machines, and
- programmed intellectual games.

Home computers

Perhaps the consumer electronic market with the greatest potential is in home computers. Sales in the U.S. were 43,000 units in 1977 growing to 200,000 in 1979. This market may very well double for 1980, and then again for 1981 as Texas Instruments and IBM introduce lower priced products. The current leaders in the home computer market are Apple, Radio Shack and Commodore. Table (4) shows the world breakdown of home computers to 1982.

Other Consumer Goods

Microprocessors are making extensive inroads in the domestic appliance markets. The most extreme case is the U.S. microwave oven market where microprocessor-based products account for 60 per cent of sales. In 1978, the U.S. consumed 2.7 million microwave units or 77 percent of the world market for microwave ovens. The U.S. also dominates production of ovens, accounting for 8 million units in 1976 (or 50 per cent of world output) compared to 3.9 million units for the EEC and 2.2 million units for Japan. In the overall U.S. range market, penetration of microelectronics was only one per cent in 1978, but is expected to grow to 15 per cent in 1980 and 30 per cent by 1985 (2). The microwave oven market in the U.S. is currently dominated by Amana and Litton industries which use components from Texas Instruments, G.I. and Fairchild. The Japanese have begun to penetrate the U.S., and world markets through companies such as Mitsubishi, Hitachi, Toshiba and Sanyo.

Substantial inroads have also been made in the utilization of microprocessors for washers and dryers, sewing machines and hair styling products.

It is anticipated that during the 1980s home computing and communications terminals, of which Telidon is an early example, will allow telephone control of intelligent appliances.

## CONSUMPTION AND PRODUCTION TRENDS IN CANADA

### Rising consumption/Falling production

Canadian consumption of consumer electronic products has been increasing dramatically over the past decade. Statistics Canada's definition of electronic consumer products covers a limited range of goods such as TVs, radios, tapes, hi-fis, hearing aids and microwave ovens. Other consumer products, such as appliances, games and toys, fall in a wide range of SIC categories which are difficult to aggregate. From 1975 to 1979 domestic consumption increased each year (with the exception of 1977) to a total value of $803.3 million in 1979 (Table 5).

This increase in consumption was satisfied not from domestic production, which has been dropping steadily as a result of market rationalization, but from rising imports. In 1964, imports accounted for 14 per cent of domestic consumption; by 1976 they accounted for 63 per cent of Canadian requirements, and in 1979 Canada imported 84.3 per cent of its total consumption of consumer electronic goods.

### TV Sets

Although the manufacture of television sets in Canada accounts for three-quarters of the output in electronic consumer products, imports of television receiving sets have more than doubled to 88 per cent of the apparent domestic market in both volume and value since the mid 1970s. The source of imports has also been changing. Sets originally supplied from Japan are now being produced in Far Eastern countries such as Taiwan, Korea and Malaysia. The Far Eastern market share was approximately 60 per cent of total Canadian imports in 1979.

Canadian exports of television sets in 1979 had a value of $30 million which went mainly to the U.S. (Table 6).

At the peak of activity there were 17 television manufacturers which were mostly foreign-owned, and many times more manufacturers of household and automobile radios, record players, and high fidelity audio equipment. The total employment was over 8,000.

Today, the number of establishments has dropped to 18, of whom only 8 have over 100 employees, only two have more than 200 employees and only one has more than 500 employees. Total employment has declined to about 2,200.

The principal cause of the demise of the Canadian TV industry was its inability to compete on the basis of price with Far Eastern countries. The domestic industry was overburdened with too many producers given the size of the Canadian market.

The introduction of semiconductors in the production of TV sets further allowed the Far Eastern producers to dominate North American markets by lowering the volume-to-price ratio, thereby decreasing transportation costs.

Audio Electronic Products

Most classes of audio electronic products have experienced rapid import growth rates over the past few years (Table 7). In tape recorders and players, imports increased 119 per cent over the period 1975 to 1979 to a total value of $93.2 million. Over 70 per cent of these imports came from Japan. Imports of car radios increased 142 per cent to a value of $57.4 million in 1979. Domestic production in 1977 totalled about $34 million - down 24 per cent from 1975.

In 1977, imports of radio receiving sets totalled $70 million, reflecting an increase of over 60 per cent from 1975. Canadian exports have also increased from $26 million in 1975 to $66.6 million in 1979. The majority of these exports are mainly to the U.S. and consist of auto radios from one facility.

Imports of radio phonographs increased almost 200 per cent from 1975 to a total value in 1979 of $78.7 million. Domestic production has been declining steadily from $20.2 million in 1975 to $9 million in 1979.

Other Consumer Products

Although starting from a low base, the imports of electronic toys and games increased almost 250 per cent over the five year period from 1975 to 1979 to a total value of $16 million. It is expected that this volume will double by 1981. The major exporting countries to Canada are the U.S., Japan and Hong Kong.

Over the period 1975 to 1979, Canada has imported about 100,000 microwave ovens. It is estimated that Canada's household penetration level of microwave ovens is under 10 per cent compared to 20 per cent for the U.S. Sales in Canada for 1980 are expected to show an increase of 46 per cent and a further 25-30 per cent in 1981.

Saturation Levels (Canada/U.S.)

Although no reliable data exists to compare consumer product penetration levels for Canada and the U.S., it is reasonable to assume that the diffusion of these products is higher in the U.S. than anywhere else because the U.S. is the primary testing ground for many of these products. On the basis of IC chip consumption, the U.S. used over 16 times the dollar value of integrated circuits used in Canada for 1979, although the population ratio is only 10:1.

PROBLEMS AND OPPORTUNITIES

The Canadian electronic consumer products industry faces serious, if not severe, problems as indicated by the fact that over 84 per cent of domestic consumption is satisfied through imports. The reason for this situation can be found in the comparative strength of foreign producers who are able to produce in volume and take advantage of technical opportunities in design and production techniques. In part, this is an example of structural change brought about by the application of microelectronic technology. For example, in the production of television sets, the Japanese industry redesigned their product in the early 1970s, replacing discrete components by IC chips and thereby reducing labour costs by up to 70 per cent. The adoption of automatic assembly methods in the U.S., Japan and Western Europe has also made an increasing contribution to cost and price reductions. The Canadian industry is still hampered by the small scale of production and the general low level of indigenous R & D, which together prevent domestic producers from taking advantage of the technical opportunities presented by the developments of integrated circuits. A federal government study on the electronics industry concluded that even with protective measures, the long-run survival prospects for TV production in Canada were not good (8). The current duty remission program on TV production in Canada might retain the industry in Canada but in a different form from the present industry.

It would appear that domestic production possibilities are limited in traditional or new product areas where economies of scale are essential for significant cost and price reductions, except where entrepreneurs can take advantage of specific market niches. Currently, Canada's comparative advantage does not lie in "hard" electronic consumer products (e.g. radios, TV's, calculators, electronic games), but in the softer areas of consumer information services. A number of European countries also feel their comparative advantage to be in the softer areas of consumer information services. Holland is currently developing an information transfer agency for Western Europe. Canada can therefore expect stiff competition in the field of software from most European nations.

Probably the most obvious application of chip technology to consumer products will be the transformation of the TV set into a home entertainment and information centre. Telidon is at the forefront of a vast range of information services to the consumer.

The demand for Canada's acclaimed Telidon videotex service will come initially from business and industry rather than the home. But if the price of Telidon terminals can be reduced from the current price of approximately $3,000 to $1,000 the entire system could be opened up to the public.

Market studies in the U.S. indicate high rates of household penetration will be achieved by home console products within the next decade. Many of these products will be oriented to entertainment and educational activities (4). By 1987, 40 per cent of all households will have home consoles/terminals compared to less than one per cent in 1977.

References:

1) Consumer electronic products are usually classified in one of the following groups: home entertainment consoles, small and large appliances, toys and games, and telephone/communications systems. This last category will be ignored here since it has been covered elsewhere in this study. For the purpose of this report, any product with IC chips that can be bought as an end or final product will be considered a consumer electronic product.

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Table 1

INTEGRATED CIRCUIT APPLICATION IN SPECIFIC PRODUCTS — 1980 — 1985 (PER CENT)

| | 1980 | 1985 |
|---|---|---|
| Computers | 31.6 | 32.1 |
| Entertainment products (cameras, games, etc.) | 28.9 | 26.7 |
| Communications Equipment | 13.5 | 13.0 |
| Clocks and watches | 7.4 | 7.2 |
| Automotive applications | 2.8 | 3.6 |
| Domestic applications | 2.5 | 3.5 |
| Control and instrumentation | 13.3 | 13.9 |
| TOTAL | 100.0 | 100.0 |

Source: ( 2 )

Table 2

CONSUMER CHIP APPLICATIONS: ROM REQUIREMENTS (8 BIT WORDS)

| | |
|---|---|
| Microwave oven | 850 — 1950 |
| Dishwasher | 600 — 1500 |
| Washing machine | 700 — 1950 |
| Dryer | 200 — 1050 |
| Refrigerator | 750 — 1500 |
| Freezer | 600 — 1050 |
| Gas oven | 900 — 1700 |
| Clock | 100 — 900 |
| Citizens Band Radio | 600 — 1000 |
| Toys and games | 200 — 2000 |

Source: ( 2 )

Table 3

MICROPROCESSOR CONSUMPTION BY SELECTED APPLICATION AREA PROJECTIONS — 1987 (THOUSANDS OF UNITS)

| | EUROPE (FRANCE, W. GERMANY, U.K.) | U.S. |
|---|---|---|
| Home Consoles | 5.600 | 70.000 |
| Toys and Games | 8.500 | 39.000 |
| Environment/protection systems | 300 | 4.000 |
| Small appliances | 30.000 | 44.000 |
| Large appliances | 11.000 | 23.000 |
| Audio entertainment | 12.000 | 22.000 |
| Health Hygiene | 6.000 | 7.000 |
| Sub Total | 73.100 | 211.000 |
| Other Applications | 54.900 | 68.000 |
| TOTAL | 128.000 | 279.000 |

Source: ( 4 )

Table 4

WORLD HOME COMPUTER MARKET
1978 — 1982
($ MM U.S.)

| | 1978 | 1980 | 1982 |
|---|---|---|---|
| Business | 200 | 450 | 765 |
| Professional | 175 | 355 | 800 |
| Home | 35 | 300 | 675 |
| Education | 15 | 35 | 115 |
| Hobbyist | 75 | 85 | 75 |
| TOTAL | 500 | 1,225 | 2,430 |

Source: ( 2 )

Table 5

CONSUMER ELECTRONIC PRODUCTS
($ MILLIONS)

| | 1975 | 1976 | 1977 | 1978 | 1979 |
|---|---|---|---|---|---|
| Consumption | 501.7 | 630.1 | 571.0 | 648.1 | 803.3 |
| Imports | 269.0 | 418.5 | 463.5 | 569.2 | 677.4 |
| Production | 264.0 | 243.2 | 163.4 | 173.7 | 253.2 |
| Exports | 31.2 | 31.6 | 55.9 | 94.8 | 127.3 |

Source: ( 7 )

Table 6

TELEVISION SETS
($ MILLIONS)

| | 1975 | 1979 |
|---|---|---|
| Consumption | 276.6 | 314.0 |
| Imports | 101.7 | 229.7 |
| Production | 176.3 | 114.4 |
| Exports | 1.4 | 30.1 |

Source: ( 5 )

Table 7

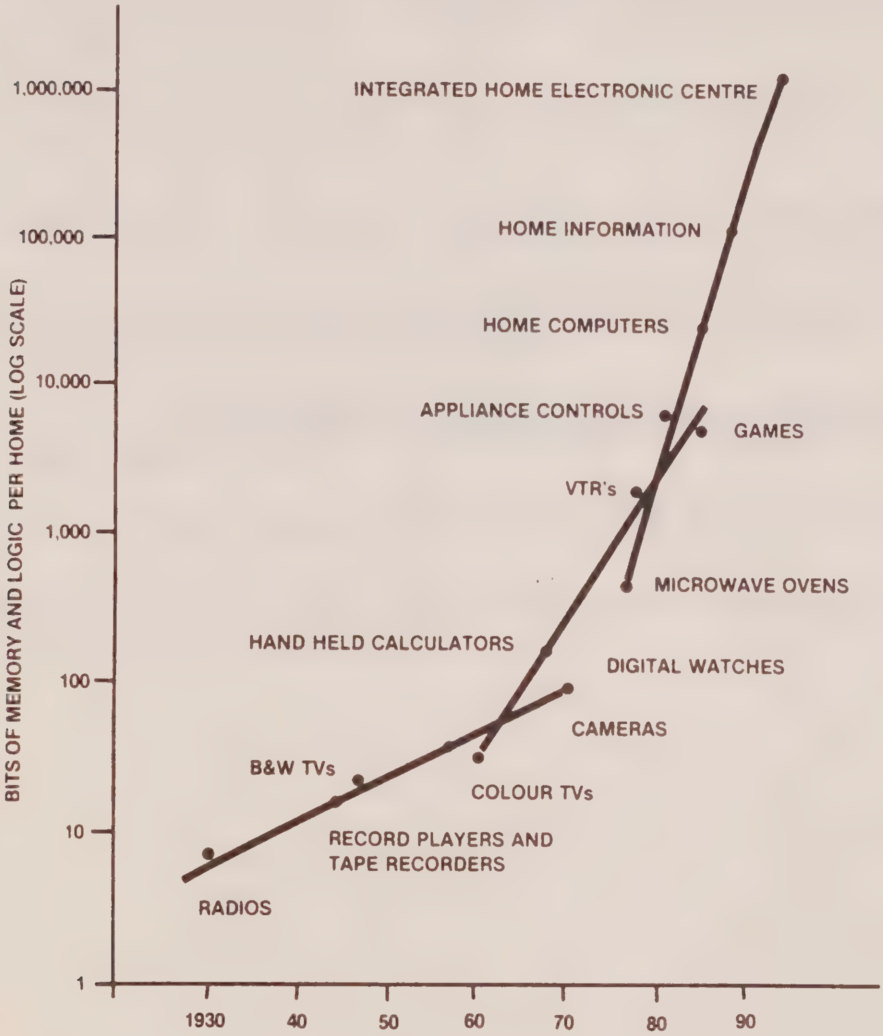
IMPORTS OF AUDIO
ELECTRONIC PRODUCTS
($'000)

| | 1975 | 1979 | % OF CHANGE |
|---|---|---|---|
| Tape recorders & players | 42,526 | 93,188 | 119 |
| Car radios | 23,759 | 57,398 | 142 |
| Radio receiving sets | 43,885 | 70,219 | 60 |
| Radio phonograph sets | 26,576 | 78,743 | 196 |

Source: ( 7 )

Figure 1

INTELLIGENT ELECTRONICS IN THE AVERAGE AMERICAN HOME




Source: ( 3 )

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